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Review of Standards of Performance for New Stationary Sources Ferroalloy Production Facilities

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A Review of Standards of Performance for New Stationary Sources — Ferroalloy Production Facilities

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16 ABSTRACT

The purpose of this study was to determine if any revisions are needed in the NSPS for Ferroalloy Production Facilities. Information was obtained from manufacturers, regulatory agencies, and the literature.

In 1979, ferroalloy production was 1.6 Tg (1,830,000 tons), which represents a 21.5 percent decline since 1971. The number of electric submerged-arc furnaces has also decreased from a total of 158 to 89 for ferroalloys and 7 for calcium carbide. No new furnaces have been built since 1974, and none are subject to the NSPS. Tests made to determine compliance with state regulations showed particulate emission rates in the range of 0.07 to 0.2 kg/MW-h (0.10 to 0.44 lb/MW-h). Fabric filter control systems are widely used on open type furnaces, and high-pressure-drop scrubbers are used on semisealed and closed furnaces. Flares are used to reduce CO emissions. Limited organic emissions data showed a range of 0.15 to 0.29 kg/MW-h (0.33 to 0.63 lb/MW-h) prior to the flare.

Because of lack of growth and an absence of new technology, no changes in the NSPS are recommended.

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Emission Standards and Engineering Division

U.S. ENVIRONMENTAL PROTECTION AGENCY
Office of Air, Noise, and Radiation
Office of Air Quality Planning and Standards
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SECTION 1

SUMMARY

The current New Source Performance Standard (NSPS) for selected ferroalloy production facilities, which was promulgated on May 4, 1976, applies to all facilities built or modified after October 21, 1974 (the original proposal date). This NSPS limits particulate emissions from electric submerged-arc furnaces to 0.45 kg per megawatt-hour (0.99 lb/MW-h) for silicon-based alloys and 0.23 kg/MW-h (0.51 lb/MW-h) for manganese and chrome-based alloys, and calcium carbide. It also regulates visible emissions from the furnace emission control device, the furnace tapping process, and any associated dust handling equipment and specifies that carbon monoxide emissions cannot exceed 20 percent by volume.

This report presents the results of a study to determine whether the current NSPS should be revised. The findings are based on information from manufacturers, regulatory agencies, and the open literature.

1.1 THE INDUSTRY

In 1971 about 2.1 Tg (2,331,000 tons) of ferroalloys (including scrap and recycled materials) were produced in the United States and an additional 0.35 Tg (388,000 tons) were imported. At that time, ferroalloys were produced at 44 locations, 145 electric furnaces were utilized, and average production was increasing by 1.5 percent per year. Another 13 furnaces were used to produce calcium carbide. Since 1972, however, domestic production has declined drastically, to a level of 1.6 Tg (1,830,000 tons) in 1979, and imports have increased to approximately 1.2 Tg (1,280,000 tons). This 21.5 percent decline in production has been accompanied by a reduction in the number of electric submerged-arc furnaces, to 89 for ferroalloys and 7 for calcium carbide. Table 1-1 shows the current electric submerged-arc furnace capacity for ferroalloy and calcium carbide production by state.

TABLE 1-1. ELECTRIC SUBMERGED-ARC FURNACE CAPACITY FOR FERROALLOY AND CALCIUM CARBIDE PRODUCTION, BY STATE

State	Plants	Capacity, MW	Furnaces	
			Ferroalloy	Carbide
Alabama	6	189	10	0
Iowa	2	50[a]	2	1
Kentucky	3	182[b]	6	2
New York	1	45	2	0
Ohio	6	554[c]	32	2
Oklahoma	1	15	0	1
Oregon	4	57	5	1
South Carolina	1	80	2	0
Tennessee	3	123	12	0
Washington	2	54	6	0
West Virginia	2	257	12	0
Total	31	1606	89	7

[a] 15 MW for calcium carbide (CaC_2).

[b] 85 MW for CaC_2.

[c] A portion of capacity at the Ashtabula plant can also be used to make CaC_2.

Because this decline in domestic production has resulted in no new plants being built since the NSPS was proposed, no plants are currently subject to this standard. Although imports have recently leveled off, no plans have been made to construct any new facilities in the near future.

Growth of the currently static domestic ferralloy industry will be affected most by the level of imports and steel production. If imports level off at their current rate and the steel industry demand increases, an optimistic growth picture would indicate the need for some new capacity by about 1985. If imports continue to supply about 50 percent of demand and growth in steel production is slow, no new facilities will be required in the next 5 years.

1.2 FERROALLOY MANUFACTURING PROCESSES AND CONTROL TECHNOLOGY

1.2.1 Manufacturing Processes

The processes used to produce ferroalloys are electric submerged-arc furnace (at 31 locations), metalothermic (at 8 locations), and electrolytic (at 4 locations). Vacuum and induction furnaces, which are in limited use, are alloy refining processes for the production of specialty metals. The widespread use of the electric submerged-arc furnace accounts for about 95 percent of production and the copious amount of fume it generates make it the only process of significance as far as air pollution is concerned.

Based on the configuration of the hood, electric submerged-arc furnaces are categorized as open, semisealed or mix-sealed, and closed. In the open furnace, which accounts for 87 percent of production capacity, the electrodes extend through a canopy hood located above the upper rim of the furnace. A 2- to 2.7-m (6- to 8-ft) gap between the furnace and the hood allows large amounts of ambient air to be drawn into the hood. As the air combines with the hot gases, the carbon monoxide and most of the organic compounds are burned and the exhaust gases are cooled and diluted. The large opening around the hood also allows fumes to escape from the furnace during upset conditions or when insufficient exhaust draft is maintained.

In the semisealed furnace the hood fits tightly onto the furnace, and raw materials are charged through annular gaps around each electrode. The hood is exhausted to an air pollution control device, but some fumes may leak out through the mix at the electrodes. No gap exists between the hood and furnace

and no dilution of the exhaust occurs; therefore no fumes can escape at that point. Because the furnace is closed, it cannot be easily stoked from the outside. This is the reason it is not in widespread use and accounts for only 12 percent of total capacity.

The closed furnace, which is used at only one plant in the United States, has a tightly fitted hood and the raw materials are fed through sealed chutes to the furnace. All fumes are exhausted to an air pollution control device. From an air pollution control standpoint, the closed furnace is the most desirable because all the fumes are exhausted through the control system. Total gas volume is only 2 to 5 percent of that from an open furnace. High silicon alloys are more difficult to produce in a closed furnace, however, because they tend to bridge over if not stoked and the closed nature of the furnace makes stoking much more difficult.

The only innovation in processing has been the introduction of a split-ring rotating furnace in which the upper and lower part of the furnace rotate at different slow speeds. Because this rotation minimizes the need for external stoking, this type of furnace would be a better process for the production of higher silicon-bearing alloys.

1.2.2 Control Technology

Particulate emissions are controlled by such conventional control systems as fabric filters, high-pressure-drop scrubbers, and occasionally electrostatic precipitators. Fabric filters are by far the most common, especially on open furnaces where large volumes of exhaust gas must be treated. They also are frequently used to reduce the particulate collected by control systems on tapping operations.

Fabric filter systems with glass filter or Nomex bags have achieved particulate collection efficiencies in excess of 99 percent and visible emissions with less than 10 percent opacity. Bag life is on the order of 1 to 2 years, and air-to-cloth ratios are about 18-38 m/h (1 to 2 ft/min).

High-pressure-drop scrubbers with pressure drops of 13.7 to 23.9 kPa (55 to 96 in. of water) also achieve particulate collection efficiencies of about 99 percent. Scrubbers are in more common use on closed and semisealed furnaces, where the volume of gas to be treated is much smaller than that from

an open furnace. Scrubbers also decrease emissions of organic matter by from 16 to 97 percent.

One electrostatic precipitator is currently in use on an open-type ferroalloy furnace in this country. The flue gas is conditioned with ammonia to achieve a high level of control efficiency at this installation.

Flares are used on semisealed and closed furnaces to reduce carbon monoxide emissions. Data on their efficiency in reducing organic emissions (both gaseous and particulate) are not available, but some reduction can be expected.

Control of furnace tapping emissions requires extensive hooding around the tapping and pouring operation, from which the collected fumes can be directed to a fabric filter control system. Installation of hoods on existing furnaces is a problem at times because of site-specific space restrictions, whereas adequate hooding can be incorporated into the installation of new facilities.

1.3 ATMOSPHERIC EMISSIONS

1.3.1 Organic Emissions

Since the NSPS was proposed, limited additional measurements have been made as part of EPA's environmental assessment studies to quantify other pollutants emitted by the electric submerged-arc furnaces in the ferroalloy industry. In addition to measuring total organic emissions, one test on a semisealed furnace and two tests on a closed furnace also identified and quantified individual polynuclear aromatic hydrocarbons. Table 1-2 summarizes the organic emission data from these studies.

TABLE 1-2. ESTIMATED ORGANIC EMISSION RATES AFTER PARTICULATE CONTROL DEVICE

Furnace type	Control device	Total organic emissions, kg/MW-h	(lb/MW-h)
Open	Fabric filter	0.20	(0.44)
	Venturi scrubber	0.29	(0.63)
Semisealed	Scrubber	0.15	(0.33)
Closed	Venturi Scrubber	0.01	(0.022)

When these emission rates are multiplied by the respective furnace capacities, estimated total annual organic emissions from electric submerged-arc furnaces are approximately 2220 Mg (2440 tons), based on 70 percent utilization. Data on polynuclear organic matter (POM) show that these compounds represented from 8.3 to 75 percent of the total organic emissions after a scrubber and before the flare. The single test on a semisealed furnace after a scrubber showed that benzo-a-pyrene (BaP) accounted for 0.84 percent of the organic emissions at a concentration of 1.64 mg/m^3. The tests on the closed furnace showed no BaP to be present.

Ground-level concentrations of organics were estimated by use of an atmospheric dispersion model (PTDIS). These estimates showed that the highest concentrations occurred 1 to 2 km from the stack and that the maximum 24-hour concentrations for a 20-MW open furnace with a scrubber were 1.0 to 1.6 $\mu g/m^3$.

Additional quantitative data on specific organic emissions are needed for a better determination of the magnitude of this potential problem.

1.3.2 Particulate Emissions

Data from tests to determine compliance of existing plants with state emission regulations showed particulate emission rates in the range of 0.07 to 0.20 kg/MW-h (0.16 to 0.44 lb/MW-h), which means they could also meet the NSPS. Particulate emissions were determined by use of EPA Methods 1 to 5. These methods proved acceptable but the safety problems inherent in sampling high concentrations of carbon monoxide in semisealed and closed furnaces must be recognized. During the EPA environmental assessment studies, particulate emissions after the control system ranged from 0.016 to 0.77 kg/MW-h (0.035 to 1.7 lb/MW-h). As operated during these tests, two of the six furnaces could not comply with the NSPS.

1.3.3 Other Emissions

Emissions of trace metals were also measured in the EPA environmental assessment studies. These tests were made on an open furnace, at the inlet to a fabric filter control system, and on a closed furnace, before and after a venturi scrubber. The major metallic emissions were composed of the product being smelted. Based on limited data, the following emissions were estimated after particulate control.

Metal	Estimated emission rate, mg/MW-h
Arsenic	62
Beryllium	0.02
Cadmium	17
Copper	8.5
Mercury	4
Lead	2.7

Thus, on a 20-MW furnace, for example, the daily emission rate for arsenic would amount to about 30 grams (0.066 lb).

Sulfur oxide emissions, though fairly dilute at 20 to 80 ppm, can amount to 0.5 to 2.0 kg/MW-h (1.1 to 4.4 lb/MW-h). Correlations between the sulfur in the feed materials and sulfur oxide emissions are not available. Nitrogen oxide emissions are very low because of the lack of oxygen in the reaction zone of the furnace.

1.4 CONCLUSIONS AND RECOMMENDATIONS

The ferralloy industry is currently characterized as an industry with no production growth and no new construction or modifications. Since the early 1970's, production has declined by about 33 percent and the number of active electric submerged-arc furnaces has decreased by about 39 percent. No changes in process or emission control technology have occurred since proposal of the NSPS in 1974.

Existing plants largely comply with state regulations governing particulate and visible emissions except during tapping and pouring operations, when visible emission limits are sometimes exceeded.

The measurement of organic emissions, including polynuclear organic matter (POM), from ferroalloy furnaces shows that these compounds are being emitted from the furnace. Additional information on organic emissions should be obtained for better quantification of these emissions and for determination of the efficiency of particulate control devices for these compounds.

Because the industry is not growing and process and control technologies have remained the same, no change in the NSPS is recommended at this time.

SECTION 2

INTRODUCTION

2.1 PURPOSE AND SCOPE

On May 4, 1976, the Environmental Protection Agency (EPA) promulgated New Source Performance Standards (NSPS) for selected ferroalloy production facilities (41 FR 18497).[1] These standards establish limits for and require testing and reporting of particulate emissions from electric submerged-arc furnaces (producing specified alloys) that were built or modified after October 21, 1974. The Clean Air Act Amendments of 1977 require that the EPA Administrator review and, if appropriate, revise such standards every 4 years [Section 111(b)(1)(B)].

This report presents the results of a review of the NSPS for ferroalloy facilities. The review covers recent and projected growth of the ferroalloy industry and describes changes in process and control technology since NSPS promulgation. Because no ferroalloy facilities are currently subject to NSPS, inquiries concerned enforcement aspects of complying with state regulations, and this review is based on compliance test results from various states, recent EPA environmental assessment studies, information from the literature, and discussions with representatives of industry, control equipment vendors, EPA regional offices, and state agencies. The information obtained from these sources was then analyzed to determine whether revisions to the NSPS are required at this time.

Available information was also gathered on other atmospheric emissions from ferroalloy furnaces to determine if other portions of the act, such as Section 111(d) or 112, should be implemented to regulate emissions.

2.2 THE INDUSTRY

When the NSPS were proposed, 44 ferroalloy production facilities were operating in the United States.[2] In 1971, the industry produced 2.11 Tg

(2,331,000 tons) of alloy,[2] and the growth rate was about 1.5 percent per year.[3] In 1967, electric submerged-arc furnaces emitted 90.7 Gg (100,000 tons) of particulates per year and were by far the major air pollution source in this industry.[4]

Table 2-1 lists the major ferroalloys and their manufacturing processes. Although calcium carbide is not a ferroalloy, it is included with this industry category because it is made in submerged-arc furnaces, has similar emission characteristics, and is sometimes produced at ferroalloy plants.

As discussed later in Section 4.1, in 1979 the industry produced only about 1.5 Tg (1,650,000 tons) of alloy at 42 locations, an indication that the industry growth rate has declined sharply in recent years. The industry has been characterized by the lack of any new facilities and the large-scale installation of air pollution control equipment on existing furnaces to comply with state emission control regulations.

TABLE 2-1. LIST OF MAJOR FERROALLOYS ACCORDING TO MANUFACTURING PROCESSES

Process	Ferroalloys
Submerged-arc furnace (Carbothermic)	Silvery iron 50% Ferrosilicon 65-75% Ferrosilicon Silicon metal Calcium silicon Silicomanganese zirconium (SMZ) High-carbon (HC) ferromanganese Silicomanganese Ferromanganese silicon Charge chrome and HC ferrochrome Ferrochrome silicon Calcium carbide
Exothermic or metallothermic	Low-carbon (LC) ferrochrome LC ferromanganese Medium-carbon (MC) ferromanganese Chromium metal, FeTi, FeV, FeCb, and FeMo
Electrolytic	Chromium metal Manganese metal
Vacuum furnace	LC ferrochrome
Induction furnace process	Ferrotitanium

REFERENCES FOR SECTION 2

1. U.S. Environmental Protection Agency. Code of Federal Regulations, Title 40, Chapter I, Part 60. Washington, D.C., Office of Federal Register. May 4, 1976.

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3. Dealy, J.O., and A.M. Killin. Engineering and Cost Study of the Ferroalloy Industry. U.S. Environmental Protection Agency, Research Triangle Park, North Carolina. Publication No. EPA-450/2-74-008. May 1974, p. II-1.

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SECTION 3

CURRENT EMISSION STANDARDS FOR ELECTRIC SUBMERGED-ARC FERROALLOY PRODUCTION FACILITIES

3.1 FEDERAL NEW SOURCE PERFORMANCE STANDARDS

The final emission standards for ferroalloy production facilities were published in the Federal Register on May 4, 1976 (41 FR 18498)[1], and applied to all facilities on which construction or modification began after October 21, 1974 (the original proposal date; 39 FR 37465).

The promulgated standards limit particulate matter and carbon monoxide emissions from electric submerged-arc furnaces and limit particulate matter emissions from dust-handling equipment. Emissions of particulate matter from the control device cannot exceed 0.45 kg/MW-h (0.99 lb/MW-h) on furnaces producing high-silicon alloys (in general) and cannot exceed 0.23 kg/MW-h (0.51 lb/MW-h) on furnaces producing chrome, manganese, and low-silicon alloys. The opacity reading of emissions from the control device must be less than 15 percent on either type of furnace, and any 6-minute period during which the average opacity exceeds 15 percent must be reported. The regulation requires that collection hoods capture all emissions generated within the furnace (no visible emissions except during furnace upset conditions) and capture all tapping emissions during at least 60 percent of the tapping time. The concentration of carbon monoxide in any gas stream discharged to the atmosphere must not exceed 20 volume percent on a dry basis. Opacity readings of emissions from dust-handling equipment must be less than 10 percent. Monitoring of the opacity of emissions from the furnace control system and the gas flow rate through the particulate collection system must be continuous.

Because the standard covers only specific alloys (those constituting the major products in the ferroalloy industry), it affects only facilities using electric submerged-arc furnaces. The electric submerged-arc process is the major production method in this industry.

The alloys affected by the standard and the applicable regulation are as follows:

Alloys subject to 0.45-kg/MW-h limit

Silicon metal
Ferrosilicon
Calcium silicon
Siliconmanganese zirconium

Alloys subject to 0.23-kg/MW-h limit

Ferrochrome silicon
Silvery iron (ferrosilicon with less than 30% silicon)
High-carbon ferrochrome
Charge chrome
Ferromanganese
Silicomanganese
Ferromanganese silicon
Calcium carbide

Other ferroalloys, such as those containing vanadium, titanium, nickel, tungsten, beryllium, and aluminum, are made in relatively small quantities by metalothermic processes. Ferrophosphorous (FeP) is produced as a slag by-product of the manufacture of phosphorous by electric arc furnaces, but the nature of the emissions and the control system are very unlike those of ferroalloy processes; therefore this product is not included under this standard.

Particulate emissions must be tested by EPA Method 5, and carbon monoxide (CO) concentrations should be measured by an Orsat according to procedures in Method 3. The electrical input to the furnace must be continuously measured during the test period, and the type of product must be identified. In addition, the opacity of the control system exhaust and the volumetric flow rate of the furnace exhaust must be monitored continuously.

3.2 STATE EMISSION LIMITATIONS FOR FERROALLOY PLANTS

State regulations pertaining to industrial processes were reviewed for those states in which ferroalloy plants are located. These state regulations are largely based on the weight rate limitations on similar processes.

The most stringent regulations are:

$E = 3.59\ P^{\cdot 62}$ for charge rates less than 30 tons/h and

$E = 17.31\ P^{\cdot 16}$ for charge rates greater than 30 tons/h

where E = allowable particulate emissions, lb/h

P = charge rate, tons/h.

The least stringent process weight regulations are:

$E = 4.10\ P^{.67}$ for charge rates less than 30 tons/h and

$E = 55.0\ P^{.11} - 40$ for charge rates greater than 30 tons/h.

Table 3-1 summarizes the state regulations in states that have facilities with submerged-arc ferroalloy processes.

Allowable particulate emissions for the alloys subject to NSPS have been calculated on the basis of a 30-MW furnace and compared with the most stringent and the least stringent state limitations (Table 3-2). It is apparent that the type of product is not a determining factor for allowable emissions in state regulations; they are based only on the process weight rate.

The data in Table 3-3 were used to estimate allowable emissions for each of the metals or alloys on a pounds-per-hour basis for easier implementation of the process weight regulations. None of the state regulations is more stringent than the lower NSPS of 0.23 kg/MW-h (0.51 lb/MW-h), but a number of state regulations are more restrictive than the NSPS for high-silicon-based products. State opacity regulations are fairly consistent. They generally limit opacity of exhaust gases from the control device to 20 percent, which is similar to the NSPS limitation of 15 percent.

The states have no carbon monoxide regulations specifically applicable to ferroalloy submerged-arc furnaces. Some states require a specific percent control on CO streams from certain refinery or metallurgical processes, such as a blast furnace or basic oxygen furnace, and others require incineration of streams from specific processes (usually cupolas, blast furnaces, and catalyst regenerators).

3.3 EMISSION REGULATIONS FOR FERROALLOY FACILITIES IN OTHER COUNTRIES

Several countries that have ferroalloy facilities have passed specific regulations for these operations. Table 3-4 presents a comparison of some of these regulations (where emissions can be shown on a common basis) with the NSPS of the United States. This comparison shows that the NSPS are the most restrictive for open furnaces, but are generally less restrictive than regulations of other countries for closed furnaces. These low emission limits on closed furnaces result from the use of a concentration-type standard multiplied by a small exhaust gas volume.

TABLE 3-1. STATE AIR POLLUTION CONTROL REGULATIONS IN STATES WITH FERROALLOY OPERATIONS

State	Particulate[a]	Opacity[b]
Alabama	$E = 3.59\ P^{.62}$ $P \leq 30$ tons/h $E = 17.31\ P^{.16}$ $P > 30$ tons/h (Class 1 county)	20%
Iowa	$E = 4.10\ P^{.67}$ $P < 30$ tons/h $E = 55.0\ P^{.11} - 40$ $P > 30$ tons/h 0.1 gr/dscf may be imposed	40%
Kentucky	$E = 3.59\ P^{.62}$ $P < 30$ tons/h $E = 17.31\ P^{.16}$ $P > 30$ tons/h	20%
New York	$E = 0.024\ P^{.67}$ $P < 100{,}000$ lb/h $E = 0.030$ gr/dscf $P > 100{,}000$ lb/h	20%
Ohio	$E = 4.10\ P^{.67}$ $P < 60{,}000$ lb/h $E = 55\ P^{.11} - 40$ $P > 60{,}000$ lb/h	20%
Oklahoma	$E = 4.10\ P^{.67}$ $P < 60{,}000$ lb/h $E = 55\ P^{.11} - 40$ $P > 60{,}000$ lb/h	20%
Oregon	Curve for $P < 60{,}000$ lb/h $E = 55\ P^{.11} - 40$ $P > 60{,}000$ lb/h	20%

(continued)

TABLE 3-1 (continued)

State	Particulate[a]	Opacity[b]
Pennsylvania	Emission = $0.76[E]^{.42}$ Where E = 0.3 P and P = charging rate in lb/h	20%
South Carolina	$E = 4.10\ P^{.67}$ P<60,000 lb/h $E = 55P^{.11}-40$ P>60,000 lb/h	20%
Tennessee	$E = 3.59\ P^{.62}$ P<60,000 lb/h $E = 17.31\ P^{.16}$ P>60,000 lb/h	20%
Washington	RACT 0.1 gr/dscf	20%
West Virginia	Process weight table or at least 99% eff. for duplicate sources[c] smaller than 125 tons/h	< No. 1 Ringelmann or equivalent opacity and not equal or exceed No. 2 Ringelmann or equivalent for 5 minutes per 60-minute period

[a] P = charge rate in tons/h in equations; E = allowable emissions in lb/h.

[b] Most states allow the stated opacity to be exceeded for 5 or 6 minutes per 60-minute period. The excursion is usually limited to 40 percent opacity.

[c] Any combination of two or more individual source operations that have the same nomenclature.

TABLE 3-2. COMPARISON OF ALLOWABLE EMISSIONS FROM FERROALLOY PLANTS UNDER NSPS AND STATE REGULATIONS[a]

Product	NSPS limitation		State regulations, lb/h	
	lb/MW-h	lb/h	Most stringent[b]	Least stringent[c]
Si metal	0.99	29.7	15.43	19.81
50% FeSi	0.99	29.7	19.24	25.16
65-75% FeSi	0.99	29.7	19.48	25.50
CaSi	0.99	29.7	14.87	19.05
SiMnZr	0.99	29.7	19.48	25.50
H-C FeCr	0.51	15.3	28.65	38.68
Chg Cr	0.51	15.3	28.65	38.68
FeMn	0.51	15.3	30.91	41.94
SiMn	0.51	15.3	23.81	31.68
CaC_2	0.51	15.3	21.88	28.91
FeCrSi	0.51	15.3	18.27	23.80
FeMnSi	0.51	15.3	25.65	34.33
Silvery iron	0.51	15.3	23.50	31.22

[a]Based on 30-MW furnace.

[b]Most stringent State allowable:

$$E\ (lb/h) = 3.59\ P^{.62} \quad \text{where } P<30 \text{ tons/h}$$
$$= 17.31\ P^{.16} \quad \text{where } P>30 \text{ tons/h}$$

[c]Least stringent State allowable:

$$E\ (lb/h) = 4.10\ P^{.67} \quad \text{where } P<30 \text{ tons/h}$$
$$= 55.10\ P^{.11} - 40 \quad \text{where } P>30 \text{ tons/h}$$

TABLE 3-3. FACTORS FOR CONVERTING TO PROCESS WEIGHT RATE
(based on a 30-MW furnace)

Product	Charge rate,		
	lb/MW-h[a]	lb/h	tons/h
Si metal	700	21,000	10.5
50% FeSi	1000	30,000	15.0
65-75% FeSi	1020	30,600	15.3
CaSi	660	19,800	9.9
SiMnZn	1020	30,600	15.3
H-C FeCr	1900	57,000	28.5
Chg Cr	1900	57,000	28.5
FeMn	2500	75,000	37.5
SiMn	1410	42,300	21.15
CaC_2	1230	36,900	18.45
FeCrSi	920	27,600	13.80
FeMnSi	1590	47,700	23.85
Silvery iron	1380	41,400	20.7

[a]Based on information in Reference 2.

TABLE 3-4. COMPARISON OF EMISSION STANDARDS FOR SELECTED FACILITIES[a]
kg/h (lb/h)

Product	Furnace size and type	United States NSPS	Quebec, Canada	Germany	Sweden[b]	South Africa[c]
Si	18 MW, open	8.1 (17.8)	11.4 (25.1)	23.7 (52.2)	19.1 (19.9)	63.2 (139)
75% FeSi	30 MW, open	13.5 (29.7)	26.2 (57.8)	31.9 (70.3)	35.0 (77.0)	85.2 (188)
SiMn	35 MW, closed	8.1 (17.8)	11.2 (24.7)	1.2 (2.6)	1.7 (3.7)	3.2 (7.0)

[a]Based on information in Reference 3.

[b]The limit for plants built before 1977 is 1.5 times these values.

[c]Based on 200 mg/m^3.

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SECTION 4

INDUSTRY STATUS

This section presents information on the current status and changes in the industry's demographic features since background information was assembled in 1974 for the new source performance standard.

4.1 PRESENT CAPACITY

Ferroalloy production in the United States has been declining over the past 9 years, primarily because imports have increased and demands have remained fairly constant. Figure 4-1, which illustrates the trends in imports and domestic production since 1970, shows that imports have more than doubled in this decade and now account for approximately 45 percent of demand.[1,2,3] Domestic consumption is essentially keyed to the production of steel. Table 4-1 shows that the consumption of ferroalloys per ton of steel has remained relatively constant for the past 10 years.[1,4] This ratio is not expected to change in the near future. The 1979 increase in domestic production shown in Figure 4-1 resulted not from increased steel production, but mainly from increases in stock levels and unreported consumption. As discussed later, this increase is not believed to represent an actual reversal in the overall downward trend in domestic production. Exports of ferroalloys have recently averaged only about 0.043 Tg (47,000 tons/yr) and consequently are not a significant factor in assessing industry capacity.

The sale of domestic plants to foreign companies is another recent development in the industry. For example, Airco has sold its plants in Calvert City, Kentucky; Charleston, South Carolina; and Niagara Falls, New York;[5] and Union Carbide recently announced the sale of all of its ferroalloy operations.[6] Although this trend does not directly influence industry growth because all the plants involved are still operating, it may tend to stem the growth in imports and precipitate some plant rehabilitation. This is highly

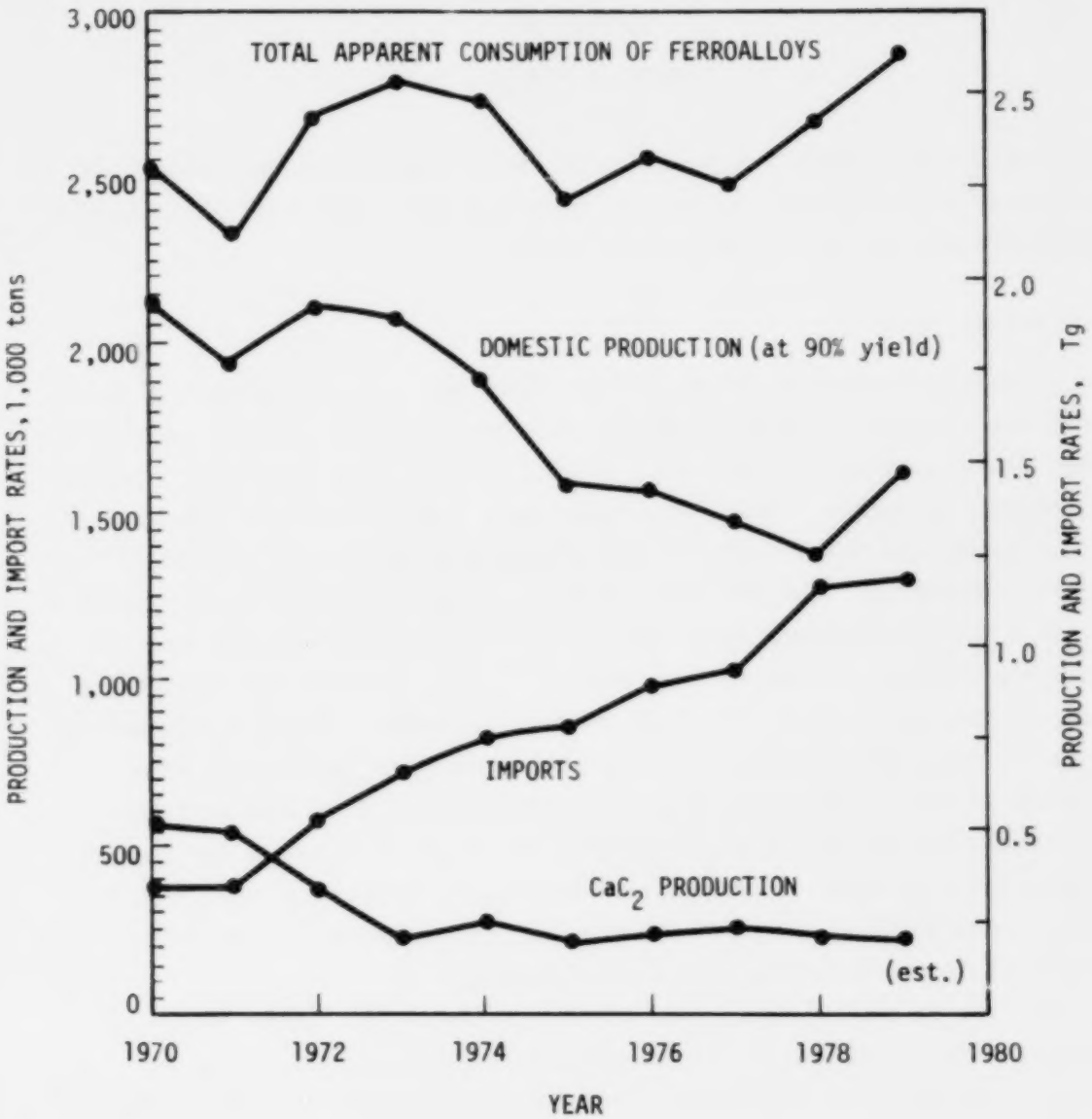

Figure 4-1. Trends in domestic production and imports.[1,2,3,4]

TABLE 4-1. REPORTED FERROALLOY CONSUMPTION AS A FUNCTION OF STEEL PRODUCTION[a]

Year	Reported domestic ferro-alloy consumption,[b] Tg (10^6 tons)	Total raw steel production,[c] Tg (10^6 ton)	Alloy steel, percent of total	Kg of ferroalloy/ Mg of steel[d] (lb/ton)
1970	2.00 (2206.5)	119.4 (131.5)	10.7	16.8 (33.6)
1971	2.05 (2260.8)	109.3 (120.4)	11.1	18.8 (37.6)
1972	2.25 (2474.7)	120.9 (133.2)	11.7	18.6 (37.2)
1973	2.73 (3008.4)	136.9 (150.8)	12.0	20.0 (39.9)
1974	2.65 (2919.6)	132.3 (145.7)	13.1	20.1 (40.1)
1975	1.90 (2097.7)	105.9 (116.6)	14.0	18.0 (36.0)
1976	2.06 (2269.6)	116.2 (128.0)	12.5	17.8 (35.5)
1977	2.13 (2340.7)	113.7 (125.3)	13.7	18.7 (37.4)
1978	2.30 (2529.3)	124.4 (137.0)	14.7	18.5 (37.0)
1979	2.28 (2506.8)	123.4 (135.9)	14.7	18.5 (36.9)

[a]Excludes CaC_2.

[b]Reference 1. Recent consumption figures (1975-1979) are estimated to be understated by about 10 percent due to incomplete reporting by consumers.

[c]Reference 4.

[d]Average consumption 1975-1979 equals 18.3 kg/Mg (36.6 lb/ton) of raw steel. This figure represents a relatively stable level of alloy steel as a percent of total steel. Consumption expressed on the basis of total steel plus ferrous foundry production is about 13 percent lower.

speculative, however. In the past five years, plants at Brilliant, Ohio; Sheffield, Alabama; and Houston, Texas, have discontinued production.

The total estimated capacity of plants in the United States for production of ferromanganese, ferrochrome, ferrosilicon, and other major ferroalloys is estimated to be 1.82 to 2.09 Tg (2.0 to 2.3 X 10^6 tons). The higher estimate is based on the furnace megawatt (MW) ratings shown in Table 4-2[7-9] and the energy requirement for the products (given in Reference 10). An annual operating time of 7884 h/yr was used, which corresponds to 90 percent utilization. Capacity for a given furnace was computed as follows:

$$\text{Capacity} = \frac{(\text{MW rating of furnace}) \times (7884 \text{ h/yr})}{\text{MW-h/ton of product}}$$

The resultant estimate is considered to be a maximum value because a 90 percent utilization rate probably could not be sustained on all furnaces over the long term. Capacity also varies with the desired product and its power requirement.

Another capacity estimate of 1.82 Tg (2 X 10^6 tons) is given in Reference 11, and an indirect capacity estimate in Reference 12 states that the industry was running "flat out" in 1979, a year in which 1.63 Tg (1.79 x 10^6 tons) was produced. The exact industry capacity is difficult to determine because many furnaces operate only part of the time, others are in cold standby condition, and still others have been dismantled. Based on the cited references, however, it appears that the industry could not satisfy a total demand of about 2.3 Tg (2.5 x 10^6 tons) without importing approximately 0.2 to 0.3 Tg (200,000 to 300,000 tons) per year.

The capacity for specific ferroalloys is difficult to estimate because most furnaces can produce several different products, depending on market conditions. Table 4-3 shows the product mix in 1979. During that year 25 to 55 percent ferrosilicon accounted for 30.7 percent of production, ferromanganese accounted for 17.4 percent, and chrome-based alloys accounted for 16.0 percent. Import penetration is highest in chrome-based alloys and manganese alloys.[1] It is likely that silicon products will continue to comprise the major share of domestic production.

The estimated calcium carbide production capacity of U.S. plants is 0.34 Tg (0.37 x 10^6 tons). This estimate was calculated in the same manner as

TABLE 4-2. FERROALLOY AND CALCIUM CARBIDE PLANTS USING ELECTRIC SUBMERGED-ARC FURNACES[7,8,9]

Producer	Plant location	Major products	Type	Furnaces Number	Size, MW	Control equipment
Airco, Inc. Carbide Div.	Louisville, Ky.	CaC_2	Open	1	50	Fabric filter and high efficiency wet scrubber
	Calvert City, Ky.	CaC_2	Open	1	35	Fabric filter
Alabama Alloys	Woodward, Ala.	50% FeSi	Open	1	7	Fabric filter
Aluminum Co. of America Northwest Alloys Inc., Div.	Addy, Wash.	Si, 75% FeSi	Open	2	20 and 25	Fabric filter
Cabot Corp. Kawecki-Berylco Industries, Inc.	Springfield, Ore.	Si	Open	1	18	Fabric filter
Chromasco, Ltd. Chromium Mining and Smelting Corp., Div.	Woodstock, Tenn.	FeCr, 50% FeSi	Open	3 and 1 standby	1 at 18.5 3 at 7.5	Ejector-type scrubber
Compania Minera Autland, S.A. de C.V.	Mobile, Ala.	SiMn	Semisealed	1	27	Scrubber on furnace and tap hood
Foote Mineral Co.[a] Ferroalloys Div.	Keokuk, Iowa	18% FeSi	Closed	2	15 and 20	Scrubbers
	Graham, W. Va.	50%, 75% FeSi	Open	3	35, 20, and 24	Fabric filter
Hanna Mining Co. Nickel Smelting Co. Silicon Div.	Riddle, Oreg.	50% FeSi	Open	1[b]	12	Fabric filter
	Wenatchee, Wash.	75% FeSi, Si	Open	3 and 1 standby	9 each	2 fabric filters and 3 furnaces

(continued)

TABLE 4-2 (continued)

Product	Plant location	Major products	Type	Furnaces Number	Size, MW	Control equipment
Interlake, Inc. Globe Metallurgical Div.	Selma, Ala.	Si	Open	2	16 and 17	Fabric filter
	Beverly, Ohio	HCFeCr, FeCrSi, Si	Open	4	9, 10, 11, and 20 (70 total[c])	Fabric filters
International Minerals and Chemicals Corp. TAC Alloy Div.	Bridgeport, Ala.	75 FeSi	Open	1	40	Fabric filter
	Kimball, Tenn.	50 FeSi	Open	1	20	Fabric filter
MacAlloy, Corp.	Charleston, S. Car.	HCFeCr	Open	2	35 and 45	ESP/Fabric filter for tapping fumes
Midwest Carbide Corp.	Keokuk, Iowa	CaC_2	Open	1	15	Fabric filter
	Pryor, Okla.	CaC_2	Open	1	15	Fabric filter
Ohio Ferro-Alloys Corp.	Montgomery, Ala.	Si	Open	3	18 each	Fabric filter
	Philo, Ohio	50, 75 FeSi FeMn, SiMn	Open Open	7	12, 20, 26, 34, 40 20, 8	4 fabric filters 3 scrubbers
	Powhatan Point, Ohio	Si	Open	4	12, 12, 12, and 18	Cyclones and fabric filters
Pacific Carbide and Alloy Co.	Portland, Ore.	CaC_2	Open	1	7 (approximately)	Venturi scrubber
Reynolds Metals	Sheffield, Ala.	Si	Open	2	12 and 16	Fabric filter
Satra Corp. Satralloy, Inc., Div.	Steubenville, Ohio	HCFeCr, FeCrSi	Open	4	10 each[d]	Fabric filter

(continued)

TABLE 4-2 (continued)

Product	Plant location	Major products	Type	Furnaces Number	Size, MW	Control equipment
SKW Alloys, Inc.	Calvert City, Ky.	FeMn, SiMn,	Open	3	2 at 15 and 1 at 14	Fabric filters
		FeSi,	Open	2	42 each	
		FeCrSi	Open	1	11	
	Niagra Falls, N.Y.	FeCrSi, 75% FeSi,	Open	2	21 and 24	Fabric filters
South African Manganese Amcor, Ltd., (SAMANCOR)	Rockwood, Tenn.	FeMn, SiMn, 50% FeSi	Open	7	11 each[e]	Fabric filter
Union Carbide Corp.[f,g]	Ashtabula, Ohio	CaC_2 50% FeSi	Semisealed	4	10, 22, 45, and 50	3 scrubbers with fabric filter on tap hoods. Large furnace has fabric filter.
			Open			
	Marietta, Ohio	SiMn, FeMn	Open	2	15 and 30	Venturi scrubbers[h]
		FeMn	Semisealed	7	12 each	Scrubbers (Buffalo Forge)
	Portland, Ore.	SiMn	Open	1	8	Fabric filter
		FeMn	Semisealed	2	6 each	Scrubber
	Alloy, W. Va.	Si, SiMn, CaSi, FeSi, FeMnSi	Open	9	15-30 (178 total)	Fabric filter and one scrubber

[a] Two open arc furnaces in Cambridge, Ohio, are not listed (8 MW total).

[b] Four ore/lime smelters at 23 MW each and two open electric arc furnaces at 1.5 MW each are used for FeNi operations and are not included.

[c] Open-arc furnace (13 MW) for ore/lime processing is also used.

[d] Two open-arc furnaces at 8 MW each are used for ore/lime processing.

[e] One electric open-arc, ore-smelting furnace at 10 MW is also used.

[f] Production discontinued at Sheffield, Alabama, early in 1980. The Niagara Falls plant has no submerged-arc furnaces.

[g] Recently acquired by a European conglomerate.

[h] Fabric filter on one tap hood.

described earlier for ferroalloys. Production has been relatively constant at 0.22 Tg (0.24 x 10^6 tons) per year.[2,3] Production rates were based on lime consumption.

TABLE 4-3. FERROALLOY PRODUCT MIX IN 1979[a]

Alloy	Percent of total
High-carbon FeCr	11.6
Low-carbon FeCr	1.8
FeCrSi	1.4
Other Cr	1.2
FeMn	17.4
SiMn	9.0
Electrolytic Mn	1.5
FeSi 25-55%	30.7
FeSi 56-96%	9.6
Si	8.0
Other silicon	5.3
Other[b]	2.5

[a]Product mix derived from data given in Reference 1, production data for FeAl, FeMo, and "other" alloys from Reference 13.

[b]Include FeAl, FeMo, FeCb, FeW, FeV, FeB.

4.2 PLANT LOCATION

Historically, the ferroalloy industry has been located in areas of relatively low electrical power cost and near steel manufacturing facilities. Table 4-2, presented earlier, lists the major submerged-arc ferroalloy and calcium carbide facilities in operation early in 1980. The table gives company name; plant location; major products; the number, type, and approximate size of the furnaces; and the air pollution control equipment applied. This listing shows a total capacity of 1606 MW at 31 locations in 11 states. Of this total capacity, 85 percent is supplied by open type furnaces, 12 percent by semisealed furnaces, and 3 percent by closed furnaces. In addition to these submerged-arc furnaces, two open-arc furnaces operated by the Foote Mineral Company in Cambridge, Ohio, produce specialty ferroalloys, and five open-arc furnaces operated by various other companies smelt ore/lime mixtures. Table 4-4 summarizes, by state, the ferroalloy production capacity of the

TABLE 4-4. ELECTRIC SUBMERGED-ARC FURNACE CAPACITY FOR FERROALLOY AND CALCIUM CARBIDE PRODUCTION, BY STATE

State	Plants	Capacity, MW	Furnaces	
			Ferroalloy	Carbide
Alabama	6	189	10	0
Iowa	2	50[a]	2	1
Kentucky	3	182[b]	6	2
New York	1	45	2	0
Ohio	6	554[c]	32	2
Oklahoma	1	15	0	1
Oregon	4	57	5	1
South Carolina	1	80	2	0
Tennessee	3	123	12	0
Washington	2	54	6	0
West Virginia	2	257	12	0
Total	31	1606	89	7

[a] 15 MW for calcium carbide (CaC_2).

[b] 85 MW for CaC_2.

[c] A portion of capacity at the Ashtabola can also be used to make CaC_2.

electric submerged-arc furnace processes. Ohio, in EPA Region V, accounts for almost one-third of the production capacity, with 34 furnaces at 6 plants. West Virginia, Alabama, and Kentucky are also major production areas.

Two other processes are also used to produce ferroalloys and related pure metals: the metalothermic or exothermic process and the electrolytic process. These methods are used to make specialty alloys or metals in relatively small quantities. Table 4-5 lists eight plants using the metalothermic process and four using the electrolytic process. Blast furnaces are not currently used in the production of ferroalloys.

4.3 INDUSTRY GROWTH

Discussions with various industry representatives and observers revealed no plans for new capacity or major expansions in the ferroalloy industry.[14-18]

Increased imports have caused a continual decline in the domestic production rate, which has resulted in plant closures. According to 1979 production figures, the ferroalloy industry was operating at 80 to 90 percent of capacity, based on the capacity estimates cited earlier. The production of calcium carbide has ranged from 0.20 to 0.23 Tg (0.225 to 0.256 x 10^6 tons) in recent years,[2,3] which corresponds to a capacity utilization of 60 to 70 percent. Some production growth is indicated for this product, which is used in the steel, foundry, and metalworking industry. For example, Airco has announced a rehabilitation program for a calcium carbide furnace in its Calvert City, Kentucky, facility.[19]

The growth of ferroalloy demand is dependent on the following factors:

- Raw steel production
- Ferrous foundry production
- Alloy and stainless steel production
- Level of imports
- Level of exports

For prediction of the demand for ferroalloys in the period 1980-1985, two scenarios are examined:

Scenario A: A high-growth scenario, possible but not likely

Scenario B: A more likely growth scenario

In Scenario A, all factors reflect a level that would normally lead to high growth, e.g., large steel growth and low imports. In Scenario B, the

TABLE 4-5. FERROALLOY PLANTS USING THE METALOTHERMIC AND ELECTROLYTIC PROCESS[7,9]

	Location	Products
Metalothermic Process		
Amax Inc. Climax Molybdenum Co. Div.	Langeloth, Pa.	FeMo
Cabot Corp. Penn Rare Metals Div.	Revere, Pa.	FeCb
Duval Div., Pennzoit Corp.	Sahuarita, Ariz.	FeMo
Engelhard Minerals and Chemicals Corp.	Strasburg, Va.	FeV
Metallburg, Inc.	Newfield, N.J.	Cr, FeCb, FeTi, FeV
Molycorp, Inc.	Washington, Pa.	FeB, FeMo, FeW
Reading Alloys, Inc.	Robesonia, Pa.	FeCb, FeV
Teledyne, Inc.	Albany, Ore.	FeCb
Electrolytic Process		
Foote Mineral	New Johnsonville, Tenn.	Mn
Kerr McGee	Hannibal, Mo.	Mn
Sedema S.A., Chemetals, Corp.	Kingwood, W. Va.	FeMn
Union Carbide	Marietta, Oh.	Mn, Cr

TABLE 4-6. TWO FERROALLOY GROWTH SCENARIOS FOR 1980-1985

Factor	Scenario A	Scenario B
Raw steel growth	2.0%/year[a]	0.9%/year[b]
Alloy and stainless steel growth	4.0%/year[c]	3.0%/year[d]
Ferrous foundry products growth	5.0%/year[e]	4.0%/year[f]
Exports + unaccounted for consumption	359,000 Mg/yr[g] (386,000 tons/yr)	239,000 Mg/yr[h] (263,000 tons/yr)
Import levels in 1985[i]	Use 1979 level of 1.16 Tg (1,280,000 tons)	50% of total domestic demand (1.23 Tg or 1,350,000 tons)
Ferroalloy usage rate[j]	17.5 kg/Mg (35 lb/ton)	16 kg/Mg (32 lb/ton)

[a]See Reference 21.

[b]See Reference 22.

[c]Value from Reference 23 + 1 percent.

[d]See Reference 23.

[e]Value from Reference 24 + 1 percent.

[f]See Reference 24.

[g]Derived from data in Reference 1, highest value in last 5 years.

[h]Derived from data in Reference 1, average for 5 years (1975-1979).

[i]Import levels are assumed values.

[j]Usage expressed as kg ferroalloy per Mg of steel plus ferrous foundry production (see Table 4-1).

factors reflect the growth level that appears to be more likely. Because only a high demand calling for new source construction (or major modifications) is of interest, a lowest possible growth scenario is not considered. Table 4-6 presents the values of the factors for each scenario.

The most difficult factor to assess is the trend in imports. There is no substantial reason to expect imports to decrease. Two factors may result in a slowing of the growth of imports: (1) Japan has cut back on ferroalloy production to conserve energy,[20] and (2) worldwide steel demand is expected to grow.[21,22] Scenario A is based on the very optimistic assumptions that the total quantity of imports remains constant through 1985 and that exports plus unaccounted for consumption remain at the high level of 1979. Scenario B is based on the assumption that imports remain at a constant percentage of domestic demand, which is somewhat optimistic. Growth in the markets using ferroalloys is moderate and not a major factor.

Based on the data in Table 4-6, the domestic demand for ferroalloy products in 1985 is expected to range from 2.0 Tg (2.25 x 10^6 tons) in Scenario A to 1.45 Tg (1.61 x 10^6 tons) in Scenario B. Table 4-7 shows the composition of these estimates.

TABLE 4-7. ESTIMATES OF FERROALLOY DEMAND IN 1985
Tg/yr (10^6 tons/yr)

Component	Scenario A	Scenario B
Demand based on steel and ferrous foundry growth and usage rate	2.85 (3.14)	2.45 (2.70)
Exports plus unaccounted for consumption[a]	0.35 (0.39)	0.24 (0.26)
Less imports	-1.16 (1.28)	-1.23 (1.35)
Total estimated domestic demand (rounded)	2.0 (2.25)	1.46 (1.61)

[a]Average exports for the period 1970-1977 were 0.043 Tg (0.047 x 10^6 tons/yr).

Figure 4-2 shows this range of domestic demand (converted to a production basis using 90 percent product yield) relative to the capacity estimates derived previously. Although the figure indicates that some expansion is

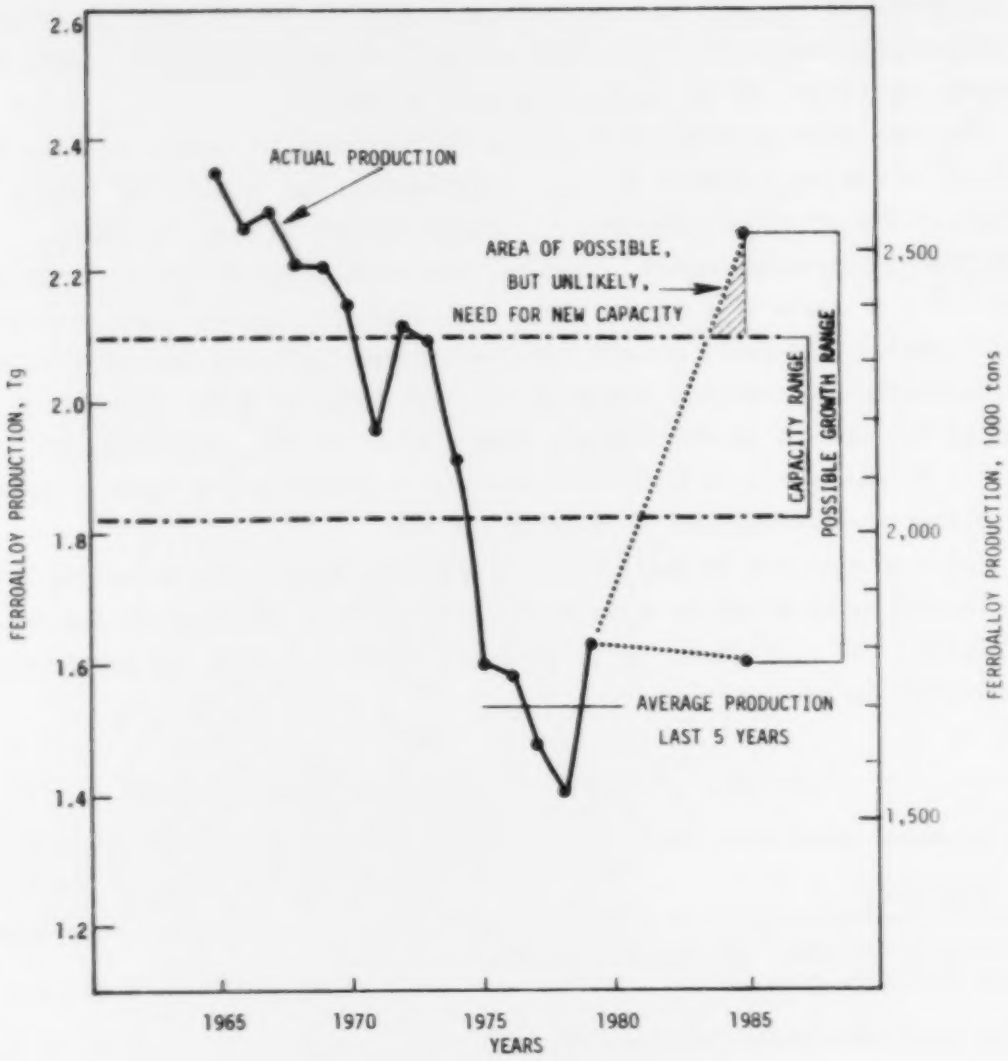

Figure 4-2. Summary of ferroalloy industry capacity and demand estimates.

conceivable (a most optimistic view), the weight of data cited in earlier references and discussion supports the conclusion that no expansion or major modifications are expected in the industry through 1985. In fact, the pessimistic view would be to assume a continuation of present trends and the resulting continued contraction of the industry. The lack of chromium and manganese ores in this country will add to the decline in production of these metals. Silicon production growth will be more favorable due to abundant ore resources and stable electrical power rates. The replacement of some existing capacity by new furnaces is possible, but no such plans by the producers are known to exist at this time.[14-17]

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SECTION 5

TEST RESULTS

Within the past few years several emission tests have been made on ferroalloy furnaces to determine their compliance with state regulations. Because such compliance is frequently based on visible emissions, manual tests often are not conducted. This lack of manual test data is due partly to the difficulty of testing open-type fabric filter systems and partly to the explosion danger inherent in closed and semisealed furnaces. No tests have been made to determine compliance with NSPS because no plants are subject to these standards.

5.1 PARTICULATE EMISSION TEST DATA

During this study, available emission test data were obtained from a number of state pollution control agencies.[1-6] These data, summarized in Table 5-1, represent information on emissions from control systems. No data were available on fugitive emissions, but the results of one test on a tapping hood system were obtained. The emission test data show that these systems could meet the NSPS, usually by a comfortable margin. Furnace emissions ranged from 0.073 to 0.20 kg/MW-h (0.16 to 0.44 lb/MW-h). No single control system provided significantly better control than any other; however, the data are insufficient for any firm conclusions to be drawn. It should also be noted that most of these data represent compliance tests on new or modified emission control systems, which means the systems were operating under essentially ideal conditions.

The EPA Environmental Assessment Studies also provide recent particulate emission test data.[7,8] Although the test methods used in these studies are not compliance test techniques, the results are useful as indications of the actual emission rate. Table 5-2 shows the types of furnaces studied and their emission controls; except on Furnaces B-1 and D-1, measurements represent

TABLE 5-1. COMPLIANCE TEST DATA

Type of furnace	Product	MW rating[a]	Type of control system	Emissions				Reference
				kg/h	(lb/h)	kg/MW-h	(lb/MW-h)	
Open	CaC_2	15	FF[b]	2.37	(5.22)	0.16	(0.35)	1
Semi-sealed[c]	CaC_2	15	FF	1.1	(2.42)	0.073	(0.16)	2
Closed	Silvery iron	15	2 venturi scrubbers in series	2.14 to 3.5	(4.7 to 7.6)	0.15 to 0.25	(0.33 to 0.54)	3
		20		2.5 to 4.1	(5.6 to 9.0)	0.12 to 0.20	(0.27 to 0.44)	
Open	Si	20	FF	3.6	(8.0)	0.18	(0.40)	4
	FeSi	25	FF	2.7	(5.9)	0.11	(0.24)	
Open	FeCr	40 (31.3)[d]	ESP[e]	0.7 to 4.1	(1.5 to 9.1)	0.022 to 0.12	(0.05 to 0.27)	5
	FeCr	40 (37.3)[d]	ESP	6.1	(13.4)	0.16	(0.36)	
Semi-sealed Tapping hood	SiMn	27	Disintegrator scrubber	4.37	9.63	0.16	0.36	6
			Venturi scrubber	2.04	4.51	0.076	0.17	

[a]Actual MW input varies according to product and load.

[b]FF = fabric filter

[c]Recently converted to open furnace, and an additional fabric filter system was added.

[d]Actual MW input during test.

[e]ESP = electrostatic precipitator.

TABLE 5-2. TYPES OF FURNACES TESTED AND THEIR EMISSION CONTROLS

Furnace	Type	Emission control	L/G, liters/m^3 (gal/1000 ft^3)
A-1	Semisealed[a]	Scrubber--high-energy, ΔP = 13.8 kPa (55.6 in. H_2O)	6.5 (49)
A-2	Open	Scrubber[b]--medium-energy, ΔP = 11.6 kPa (46.5 in. H_2O)	0.61 (4.6)
B-1	Open	Fabric filters	-
B-2	Semisealed	Scrubber--high-energy, ΔP = 20.1 kPa (81 in. H_2O)	4.0 (30)
C-1[c]	Semisealed	Scrubber--low-energy, disintegrator-type	8.0 (59.6)
C-2[c]	Semisealed	Scrubber--low-energy, disintegrator-type	8.5 (63.9)
D-1&2	Sealed	Scrubber--high-energy, ΔP = 22.4 kPa (90 in. H_2O)	2.0 to 3.2 (15 to 24)

[a]Semisealed furnaces vary in the degree of undercover combustion. Combustion was essentially complete in Furance A-1 during the tests, but it was substantially less than complete in the other semisealed furnaces tested.

[b]Designed for high energy, but operating at medium energy during test.

[c]Furnaces are now shut down.

controlled emissions. Tests on Furnace D were made under two different operating conditions (D-1 and D-2) and the two sets of data on this furnace cannot be compared with each other. Table 5-3 summarizes the particulate test data obtained in these studies. In all cases where a scrubber was used, tests were made at the outlet (except on Furnace D-1), and the inlet data were then calculated from the particulate removed by scrubbers. In all cases, tests were made prior to any flares.

The particulate emissions data in Table 5-3 show that most furnaces would comply with the NSPS (even though they were not subject to these standards). Furnace A-2, an open furnace producing FeMn, exceeded the NSPS limit of 0.23 kg/MW-h (0.51 lb/MW-h) by 50 percent. Furnace C-2 exceeded the NSPS limitation of 0.45 kg/MW-h (0.99 lb/MW-h) for ferrosilicon production by about 70 percent. This was a semisealed furnace equipped with a low-pressure-drop, disintegrator-type scrubber. The low emission rate of 0.016 kg/MW-h (0.035 lb/MW-h) measured on Furnace D-2 was obtained after a venturi scrubber with a pressure drop of 22.4 kPa (90 in. of water). No fabric filter outlet data were obtained during these assessment studies, probably because it is difficult to sample open-type fabric filters.

5.2 VISIBLE EMISSIONS

Visible emission readings are made by enforcement personnel from state and EPA Regional Offices. These readings, which are made according to EPA Method 9, are made on emissions from control equipment vents and roof openings to determine compliance with state regulations. Apparently no visible emission data have been taken directly at the tapping station.

Table 5-4 summarizes visible emission readings taken at a plant whose open furnaces are equipped with fabric filter control systems.[9] This is an older plant and is not subject to NSPS. During normal operations opacity of visible emissions from the fabric filter vent system was consistently under 10 percent (well under the NSPS limit of 15 percent); however, when the system operated with a broken bag, opacity readings averaged 22.5 percent over the maximum 6-minute period. Tapping operations on the two 40-MW furnaces caused opacity of visible emissions at the roof monitor to be much higher. "Normal" taps produced opacities averaging approximately 30 percent over the worst 6-minute

TABLE 5-3. PARTICULATE EMISSION DATA FROM EPA ENVIRONMENTAL ASSESSMENT STUDIES[7,8]

Furnace	Type	Product	Operating power, MW	Exhaust gas[a]			Particulates						
							Before control[b]			After control			
				Dry std. m^3/min (dscfm)	°C (°F)	% CO	mg/m^3	kg/MW-h	kg/Mg	mg/m^3	kg/MW-h	kg/Mg	Control eff., %
A-1	Semisealed	FeMn	11.4	255.1 (9,010)	52 (126)	0.60	3,090	4.15	10.1	49.9	0.067	0.164	98.4
A-2	Open	FeMn	15.8	3355 (118,495)	32 (90)	-	912	11.07	26.0	27.7	0.337	0.791	97.0
B-1	Open	50% FeSi	48.4	5750 (203,052)	348 (658)	0	1,364	9.72	49.2	-	-	-	-
B-2	Semisealed	50% FeSi	48.0	150 (5,296)	52 (126)	85[c]	49,750	9.33	46.0	248.8	0.0466	0.230	99.5
C-1	Semisealed	75% FeSi	15.5	156.5 (5,526)	68 (155)	28.2	20,950	12.69	103.0	825.1	0.500	4.06	96.1
C-2	Semisealed	50% FeSi	16.8	171 (6,053)	51 (123)	24.5	18,000	11.18	68.9	1242	0.771	4.75	93.1
D-1	Closed	FeMn	17.3	72.0 (2,550)	388 (730)	-	68,000	17.0	37.5	-	-	-	-
D-2	Closed	SiMn	22.5	90.6 (3,200)	47 (117)	76	-	-	-	64	0.016	0.062	-

[a] All measurements except those on B-1 and D-1 are after the particulate control device. Based on SASS test data.

[b] Inlet data represent calculations based on solids picked up in the scrubber (except those for B-1 and D-1, which are actual measurements).

[c] Reported by owner.

- means not measured.

TABLE 5-4. VISIBLE EMISSION READINGS[9]

Emission point	Operation	Average opacity readings, %	
		Highest 6-minute reading	Next highest 6-minute reading
Fabric filter serving two open furnaces	Normal	2.7	1.5
	Normal and tapping	0.4	0.2
	Normal	5.6	5.0
	Broken bag	22.5	8.3
Roof monitor over two 40-MW open furnaces	Normal	19.2	16.0
	Normal	8.8	8.3
	Casting	17.3	12.5
	Tapping	29.8	27.1
	Tapping	31.7	12.1
	Tapping	18.1	5.2
Roof monitor over one open furnace	Normal	0	0
	Normal	1.5	0
	Tapping	0	0
	Tapping	0	0
	Ladle mixing	47.3	29.6
	Ladle mixing	40.4	22.7
	Ladle mixing	36.7	34.6

period. Tapping periods for these furnaces lasted about 36 minutes. The NSPS limits the occurrence of visible emissions at the tapping station to no more than 14.4 minutes (40% x 36 min.). The roof monitor over a single smaller open furnace showed no visible emissions during normal operation and two tapping cycles. Uncontrolled hot metal mixing performed in open ladles in this building caused visible emissions averaging about 40 percent at the roof monitor. Fabric filter systems used on crushers and a screening operation produced no visible emissions at the plant.

Information received from air pollution control offices in Ohio (the State with the most ferroalloy plants) showed that most plants complied with a 20 percent opacity regulation; only two furnaces had violations during tapping.[10] Data on another Ohio plant showed zero opacity except during tapping, when roof monitor emissions exceeded 20 percent opacity throughout almost all of the tapping period.[11] Maximum readings of 100 percent opacity occurred several times during some tapping periods at this plant.

Region III of the EPA issued a notice of violation to a plant in West Virginia for opacity violations of the State regulation during tapping and casting operations.[12]

5.3 EMISSIONS OF ORGANIC MATTER

Organic compounds have been identified in both the furnace emissions and scrubber water discharges from submerged-arc ferroalloy furnace systems. Organic emissions data were also obtained in the two recent EPA environmental assessment studies,[7,8] but quantitative data on specific compounds are extremely limited. In addition, all available organic concentration data represent measurements taken prior to the flare on the vent to the atmosphere.

5.3.1 Gaseous Organic Emissions

Table 5-5 summarizes the organic emission data obtained in the two EPA-sponsored studies.[7,8] These data indicate that the furnaces emitted a wide range of organics, i.e., before any control system. Concentrations of organics before any control are much higher from the semisealed and closed furnaces than the open type because less dilution occurs and no oxygen is available for

TABLE 5-5. ORGANIC EMISSION DATA[a]

Furnace	Type	Product	Operating power, MW	Before control[b]			After control[c]			Control eff., %
				mg/Nm^3	kg/MW-h	kg/Mg	mg/Nm^3	kg/MW-h	kg/Mg	
A-1	Semisealed	FeMn	11.4	46.7	0.063	0.154	20.0	0.027	0.0657	57
A-2	Open	FeMn	15.8	28.6	0.347	0.815	24.0	0.291	0.684	16
B-1	Open	50% FeSi	48.4	34.7	0.247	1.25	-	-	-	-
B-2	Semisealed	50% FeSi	48.0	5829	1.60	7.89	284	0.053	0.262	97
C-1	Semisealed	75% FeSi	15.5	2089	1.27	10.3	487	0.295	2.40	77
C-2	Semisealed	50% FeSi	16.8	953	0.592	3.65	196	0.122	0.749	79
D-1	Closed	FeMn	17.3	1202	0.30	0.66	-	-	-	-
D-2	Closed	SiMn	22.5	-	-	-	50	0.012	0.047	-

[a]All data are from EPA Level I tests utilizing Source Assessment Sampling System (References 7 and 8).

[b]Inlet data (before any control device) represent calculations based on organics picked up in the scrubber (except those for B-1 and D-1, which are actual uncontrolled measurements).

[c]All measurements except those for B-1 and D-1 are after a particulate control device and prior to a flare (if used).

- Means not measured.

combustion at the top of the furnace. The average concentration was 31.65 mg/Nm^3 (0.013 gr/scf) from the two open furnaces, compared with 2518 mg/Nm^3 (1.1 gr/scf) from the three semisealed and one closed furnace (not including A-1). The lower organic concentration in Furnace A-1 is due to combustion that reportedly occurred even though it was a semisealed furnace.

The range of emissions on a weight basis is 0.063 to 1.6 kg/MW-h (0.14 to 3.5 lb/MW-h). Before the particulate control system, the quantity of organic emissions was relatively small compared with the particulate emissions (material collected in the probe, cyclones, and on the filter, as shown in Table 5-3). On a basis of kg/MW-h, organic emission rates were 1.5 to 17.1 percent of the particulate emission rates. In contrast, organic compounds after the particulate scrubber systems represented a much larger percentage of emissions (15.8 to 113.7 percent) compared with particulate emissions. In all cases, however, organic emissions were reduced by passage through a scrubber. The nonfilterable portion of the organic emissions (i.e., the portion that passed through the sampling train filter) ranged from 67 to 92 percent at the scrubber outlets. On Furnace B-1 the nonfilterable portion of organic emissions was 77 percent of the total before the fabric filter. The remaining 23 percent were trapped in the probe or on the filter of the sampling train. Only 1 percent of the organic emissions were collected on the sampling train filter and probe in the scrubber inlet test on Furnace D-1.

To estimate the reduction in particulate by passage through a flare, one testing company heated samples from closed furnace emission tests in an oven at approximately 482°C (900°F), the temperature at which particulates ignite.[3] When the samples were reweighed, they had lost from 68 to 87 percent of their original dry weight. These fired samples were then returned to the oven and held at 697°C (1290°F) for 15 minutes; a further weight loss of approximately 11 percent was obtained. This overall weight loss of 79 to 98 percent was probably due largely to the combustible content of the particulates. Of course, other volatile compounds or metals would have been part of this weight loss.

The use of coal and, to a lesser extent, coke and wood chips and the lack of oxygen in the furnace can contribute to the formation of organic compounds. Data in Table 5-6 summarize the percent of coal, coke, and wood feed materials and the organic emissions from the furnaces tested in EPA's environmental

TABLE 5-6. ORGANIC EMISSION RATES AND REDUCTION MATERIALS CHARGED TO FURNACES[a]

Furnace	Organic emissions before control, kg/MW-h	Reduction material in charge, % by weight		
		Coal	Coke	Wood
A-1	0.063	0	18.7	0
A-2	0.347	0	16.8	0
B-1	0.247	22	0	14.3
B-2	1.600	17.5	7.8	0
C-1	1.270	21	0	29.8
C-2	0.592	21.5	1.7	9
D-1	0.300	3.0	11.9	0
D-2	-	2.6	11.8	0

[a] Information for A, B, and C furnaces is based on Reference 7; information for D furnaces, on Reference 8.

assessment studies.[7,8] Based on these limited data, correlations between feed materials and organic emissions apparently do not exist, and the use of coal does not have a major impact on the amount or the characteristics of these emissions.

Compounds in the polycyclic organic matter (POM) classification, also commonly referred to as polycyclic or polynuclear aromatic hydrocarbons (PAH), have been identified in the organic fraction of the furnace emissions. Data on individual POM compounds that were identified in three tests are summarized in Table 5-7. These emissions include data from a single semisealed furnace producing 50 percent FeSi and one closed furnace producing SiMn and FeMn. All of the concentrations were measured before a flare, and in the case of the FeMn product, also before a scrubber. Higher POM concentrations were found in the lighter compounds with a mass of less than about 228 (chrysene and benz(a)anthracene).

Total POM compounds after the scrubber on the closed furnace amounted to 1.0 g/MW-h (2.2×10^{-3} lb/MW-h) and were much lower than those from the semisealed furnace, which totaled 91 g/MW-h (200×10^{-3} lb/MW-h). This lower emission rate is probably due more to the high-energy venturi scrubber on the closed furnace [22.4 kPa (90 in. of water)] than to any major process variable. Emissions from the semisealed furnace were controlled by a low-energy scrubber. Based on the closed furnace data, it appears that the high-pressure-drop venturi scrubber is a very effective means of reducing the higher-molecular-weight, less volatile POM compounds.

Several of the measured POM compounds are suspected carcinogens. These include benz(a)anthracene, chrysene, indo(1,2,3-cd)pyrene, benzo(j)fluoranthene, and benzo(a)pyrene. Of these, benzo(a)pyrene amounted to 1.0 g/MW-h (2.2×10^{-3} lb/MW-h) from the semisealed sealed furnace before the flare. This compound was not detected in emissions from the closed furnace.

5.3.2 Aqueous and Solid Waste Organic Emissions

Limited data are available on the organic content of both liquid and solid wastes, but specific compounds are not identified. The only contact-type process-water discharge is found in plants equipped with scrubbers for particulate control. Boiler blowdown and cooling tower water blowdown are other

TABLE 5-7. POLYNUCLEAR ORGANIC COMPOUND EMISSIONS[7,8]

Compound	Semisealed furnace Test C-2, during 50% FeSi production		Closed furnace Test D-2, during SiMn production		Closed furnace Test D-1, during FeMn[a] production	
	mg/Nm^3	g/MW-h	mg/Nm^3	g/MW-h	mg/Nm^3	g/MW-h
Fluorene	75.0	45.9	1.5	0.36	16.0	4.0
Carbazole	b				9.6	2.4
Anthracene	18.3	11.2				
Phenanthrene	18.3	11.2	2.1	0.51	220.0	54.9
Cyclopenta(def)phenanthrene	10.7	6.5				
Methyl-anthracenes			0.070	0.017	24.0	6.0
9-methylphenanthrene	1.5	0.92				
Fluoranthene	27.4	16.7	0.24	0.058	220.0	54.9
Pyrene	28.5	17.4	0.22	0.053	2.3	0.57
Methylpyrene	0.07	0.04	0.005	0.0012	14.0	3.5
Benzo(ghi)fluoranthene	8.9	5.4				
Benzo(a) and benzo(b) fluorene	1.24	0.75				
Chrysene	8.1	4.9				
Benz(a)anthracene	10.5	6.4	0.016	0.0039	49.0	12.0
Methyl chrysenes					5.2	1.3
7,12-dimethyl benz(a)anthracene	0.81	0.49			0.58	0.14
Benzo(e)pyrene					51.0	13.0
Benzofluoranthene	3.5	2.1				
Benzo(j)fluoranthene	0.16	0.10				
Benzo(k)fluoranthene	3.5	2.1				
Benzo(e)acephenanthylene	0.43	0.26				
Perylene	1.64	1.00			3.1	0.77
Benzo(a)pyrene					1.2	0.30
Methylbenzopyrenes	1.10	0.67			0.39	0.10
3-methylcholanthene	3.2	1.9			6.0	1.5
Indeno(1,2,3-cd)pyrene	0.83	0.51			1.4	0.35
Benzo(ghi)perylene					0.90	0.22
Anthanthrene					0.079	0.020
Dibenzo(a,h)anthracene					0.54	0.13
Dibenzo(c,g)carbazole					0.51	0.13
Dibenzo(ai+ah)pyrenes						
Coronene	1.0	0.61				
Total		91.0		1.0		156.0

[a] Before scrubber.

[b] Blanks indicate compound not detected.

wastewater sources. Solid wastes, however, are generated by all plants in the form of collected particulates, slag, broken fabric filters, and sludge (when scrubbers are used).

Table 5-8 summarizes data on the organic content of scrubber water outlet streams obtained in the recent EPA Environmental Assessment Study.[7] Individual organic compounds were not quantified, but a number of high-molecular-weight compounds were identified in the scrubber water of Furnace C-2. The more predominant identified compounds were:[13]

Fluoranthene and/or pyrene
Benzo(a)pyrene and/or perylene and or 10, 11-benzofluoranthene
$C_{15/16}$ benzopyrene, possibly with a naphthalene group.

Analyses of grab samples of particulate collected in fabric filters on open furnaces showed concentrations of organics in the range of 65 to 384 ppm by weight.[10] In one case, POM compounds accounted for 1 to 3 percent of the total organics in the particulate. Concentrations of 7031 ppm of organics were detected in the particulate matter from a fabric filter controlling the emissions leaking from the top of a mix-sealed furnace, and POM accounted for 15 to 20 percent of these organic compounds.[14]

Other studies on organic concentrations in liquid streams include data on the oil content of wastewater streams, which indicate a concentration of less than 2 ppm by weight.[15]

5.4 OTHER ATMOSPHERIC EMISSIONS

Limited data have been obtained on other atmospheric emissions from ferroalloy furnaces. These include data on sulfur acids, gaseous hydrocarbons, and metals.

5.4.1 Sulfur Oxides

A joint EPA-Ferroalloy Association report on ferroalloys stated that sulfur oxide emissions were less than 20 parts per million (ppm) and never exceeded 3.2 kg/h (7 lb/h).[16] For this reason, sulfur oxides are rarely included in an emission test program. The results of one set of recent tests showed concentrations of 69 to 74 ppm for a 20-MW silicon open furnace and 83

TABLE 5-8. ORGANIC CONCENTRATIONS IN SCRUBBER WATER DISCHARGE STREAMS

Furnace	mg/liter	kg/MW-h
A-1	11.2[a]	0.11
A-2	14.1[b]	0.12
B-2	551	1.55
C-1	134	0.97
C-2	71	0.48

[a] 8.2 percent adsorbed on solids.

[b] 44 percent adsorbed on solids.

ppm from a 25-MW ferrosilicon open furnace.[4] These concentrations amount to approximately 45.5 kg/h (100 lb/h) for each furnace, or 1.8 to 2.1 kg/MW-h (4 to 4.6 lb/MW-h).

This value is considerably higher than the previously reported data, possibly because of the higher sulfur content of the petroleum coke used in the electrodes. Because the sulfur content of the feed materials was not measured during the emission test, however, no direct correlation between feed composition and emissions can be made.

5.4.2 Nitrogen Oxides

No measurements have apparently been made for these compounds, but concentrations are expected to be very low because of the lack of oxygen in the reaction zone.

5.4.3 Inorganic Constituents

Tests for the inorganic constituents of the furnace exhaust gases were conducted on three furnaces as part of EPA's environmental assessment studies.[17,18] Table 5-9 summarizes the results of these tests. The tests on Furnaces D-1 and B-1 (both open furnaces) were performed on the gas stream preceding particulate control systems, and the test on Furnace D-2 (a closed furnace) was performed on the gas stream after it had passed through a venturi scrubber with a high pressure drop. Analyses of these samples were performed largely by spark source mass spectrometry techniques on each fraction of the sample collected with a source assessment sampling system. The fractions were then added to obtain the values in Table 5-9. Arsenic, mercury, and antimony were analyzed by atomic absorption.

Although data from the tests on Furnaces D-1 and D-2 cannot be directly compared (because they made different products), the much lower values for all elements obtained in the test on Furnace D-2 after the scrubber still show that the scrubber was very effective in reducing the emissions. The composition of these components varies widely, depending on the material charged. Major components were not quantified because they could not be analyzed by these techniques.

TABLE 5-9. INORGANIC CONSTITUENTS IN FURNACE EXHAUST GAS[a] ($\mu g/m^3$)[b]

Element	Furnace D-2	Furnace D-1	Furnace B-1	Element	Furnace D-2	Furnace D-1	Furnace B-1	Element	Furnace D-2	Furnace D-1	Furnace B-1
Aluminum	MC[c]	d	23,142	Holmium	0.21	30	0.5	Rhodium			
Antimony	0.54	1,900	364	Hydrogen	NQ	NQ	NQ	Rubidium	17	MC	119
Arsenic	250	48,000	122	Indium	STD	STD	STD	Ruthenium	0.2	0	
Barium	MC	MC	6,555	Iodine	0.04	6,000	9.6	Samarium	1.1	140	2.4
Beryllium	0.07	10	0.19	Iridium				Scandium	0.15	50	25.4
Bismuth	0.20	560	83.6	Iron	MC	MC	MC	Selenium	0.82	1,500	48.1
Boron	1.4	870	30.3	Lanthanum	3.2	400	37	Silicon	MC		MC
Bromine	2.4	19,000	2,075	Lead	11	MC	1,700	Silver	0.57	1,000	972
Cadmium	MC	6,700	255	Lithium	17	1,300	161.9	Sodium	MC		359.7
Calcium	MC	MC	MC	Lutetium	0.03	5	0.02	Strontium	MC	12,000	747
Carbon	NQ[e]	NQ	NQ	Magnesium	MC		1,000	Sulfur	MC	700	880
Cerium	4.0	610	126	Manganese	MC	MC	187	Tantalum	0.04		0.2
Cesium	1.5	1,300	8.2	Mercury	17	510	0.54	Tellurium	0.03	280	26.6
Chlorine	MC	MC	130	Molybdenum	5.5	3,000	57.2	Terbium	0.072	20	0.18
Chromium	MC	5,200	810	Neodynium	2.7	180	4.3	Thallium	1.2	3,000	7.6
Cobalt	1.2	10,000	42.3	Nickel	MC	4,000	562	Thorium	2.0	100	185
Copper	MC	34,000	MC	Niobium	2.6	80	1.6	Thulium	0.032	6	0.04
Dysposium	0.34	50		Nitrogen	NQ	NQ	NQ	Tin	0.94	300	2,255
Erbium	0.20	20	0.48	Osmium				Titanium	MC	7,700	317.7
Europium	0.13	30	0.5	Oxygen	NQ	NQ	NQ	Tungsten	0.19	1,200	4.7
Fluorine	MC	MC	969	Palladium				Uranium	2.5	190	141
Gadolinium	0.27	50	1.3	Phosphorus	MC		MC	Vanadium	20	800	14.6
Gallium	7.2	3,600	473	Platinum				Ytterbium	0.14	30	0.2
Germanium	1.2	280	210.6	Potassium	MC	MC	52	Yttrium	6.8	140	2.3
Gold	0.001			Praseodymium	2.1	70	51	Zinc	MC	MC	MC
Hafnium	0.32	2	0.2	Rhenium	0.03			Zirconium	21	560	7.1

[a] Data for Furnaces D-1 and B-1 were measured prior to particulate control; D-2 data were measured after a venturi scrubber.

[b] To convert to mg/MW-h, multiply concentrations for Furnaces D-1 and D-2 by 0.25 and concentrations for Furnaces B-1, by 7.1.

[c] MC = Major components.

[d] All blanks indicate elements below detectable level; detection limit 0.1 ppm.

[e] NQ = Not quantified.

Of special concern are those metals the EPA has designated as priority pollutants. These are summarized in Table 5-10 on a mg/MW-h (10^{-6} lb/MW-h) basis.

No detailed data on particle size were obtained in these assessment studies, but the cyclone catch in the particulate sampling trains confirms previous data indicating that the particulates are largely less than 10 micrometers and frequently less than 1 micrometer in diameter.

TABLE 5-10. FURNACE EMISSION RATES OF SELECTED METALS[a]
[mg/MW-h (10^{-6} lb/MW-h)]

Metal	Furnace--product					
	D-2--SiMn		D-1--FeMn		B-1--50% FeSi	
Antimony	0.13	(0.29)	475	(1,046)	2,584	(5,692)
Arsenic	62.5	(138)	12,000	(26,432)	866	(1,907)
Beryllium	0.017	(0.037)	2.5	(5.5)	1.3	(2.9)
Cadmium	MC		1,675	(3,689)	1,811	(3,990)
Chromium	MC		13,000	(28,630)	5,751	(12,667)
Copper	MC		8,500	(18,720)	MC	
Lead	2.75	(6.06)	MC		MC	
Mercury	4.25	(9.36)	127	(280)	3.8	(8.4)
Nickel	MC		1,000	(2,200)	3,990	(8,790)
Selenium	0.21	(0.46)	375	(826)	342	(753)
Silver	0.14	(0.31)	250	(551)	6,901	(15,200)
Thallium	0.30	(0.66)	750	(1,650)	54	(119)
Zinc	MC		MC		MC	

MC = Major component.

[a]Rates for D-1 and B-1 represent uncontrolled emissions; rates for D-2 represent measured emissions after a venturi scrubber.

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17. Reference 7, pp. 119 and 120.

18. Reference 8, pp. 47 and 48.

SECTION 6

PRODUCTION PROCESSES AND BEST AVAILABLE CONTROL TECHNOLOGY

Because no ferroalloy facilities in the United States are subject to NSPS, this section deals with process changes, the best control technology currently available, and the operational problems of this technology. It also presents cost data for fabric filter systems, by far the predominant method of emission control.

The type of particulate emission control used varies with the type of furnace. Scrubbers predominate on closed and semiclosed furnaces, and fabric filters are by far the most widely used control devices on open furnaces. Tapping fumes are generally vented to fabric filter systems (either separate systems or the furnace's own control system).

6.1 FERROALLOY PRODUCTION PROCESSES

As described in Section 4, ferroalloys are produced by the following processes:[1] electric submerged-arc furnace at 31 locations, metalothermic at 8 locations, and electrolytic at 4 locations. The single blast furnace, in operation until a few years ago, is no longer in use.[1] Vacuum and induction furnaces, which are in limited use, are alloy refining processes for the production of specialty metals. Only the electric submerged-arc furnace is significant as far as air pollution is concerned, partially because of its widespread use and partially because of the copious amount of fume it generates. This is the only ferroalloy production furnace subject to the NSPS, and it is still the major method for producing ferroalloys.

Ferrophosphorous is a byproduct of manufacturing phosphorous by the electric arc furnace process. The emissions from this process are unique

because the product (phosphorous) is condensed and collected from the furnace exhaust gas stream. The ferrophosphorous is a slag byproduct that is periodically tapped from the furnace.

6.1.1 Electric Submerged-Arc Furnaces

Descriptions of the electric submerged-arc furnace can be found in the open literature, and they are reviewed only briefly here.[2,3]

Figure 6-1 is a flow diagram of a typical ferroalloy production facility. The electric submerged-arc furnace in which the smelting takes place consists of a hearth lined with carbon blocks. Openings in the hearth permit tapping (or draining) of metal and slag. The steel furnace shell and its hood or cover components are water-cooled to protect them from the heat of the process. Carbon electrodes are vertically suspended in a triangular formation above the hearth. Normally there are three (sometimes more), and they may be prebaked or of the self-baking, Soderberg type. These electrodes extend 1 to 1.5 m (3 to 5 ft) into the charge materials. Three-phase current arcs through the charge materials from electrode to electrode, and the charge is smelted as the electrical energy is converted to heat. Coke and other reducing materials that are added to the furnace react chemically with the oxygen in the metal oxides to form carbon monoxide and reduce the ores to base metal. The furnace emits byproduct carbon monoxide along with entrained particulate matter and metal vapors.

Power is applied to the furnace on a continuous basis, and feed materials may be charged continuously or intermittently. Molten ferroalloy and slag are intermittently tapped into ladles from tap holes in the lower furnace wall. (Furnaces producing calcium carbide may be intermittently or continuously tapped.) The melt is poured from the ladles into molds or casting machines. After the product cools and solidifies, it is crushed, sized, and loaded into rail cars for shipment. Slag may be disposed of in landfills, but most is sold for road ballast.

For reduction of atmospheric emissions, the furnaces and tapping stations are hooded and the off-gases are ducted to a particulate control device (scrubber, fabric filter, or electrostatic precipitator). The configuration of the hood and/or furnace roof determines whether the furnace is categorized as open, semisealed, or closed.

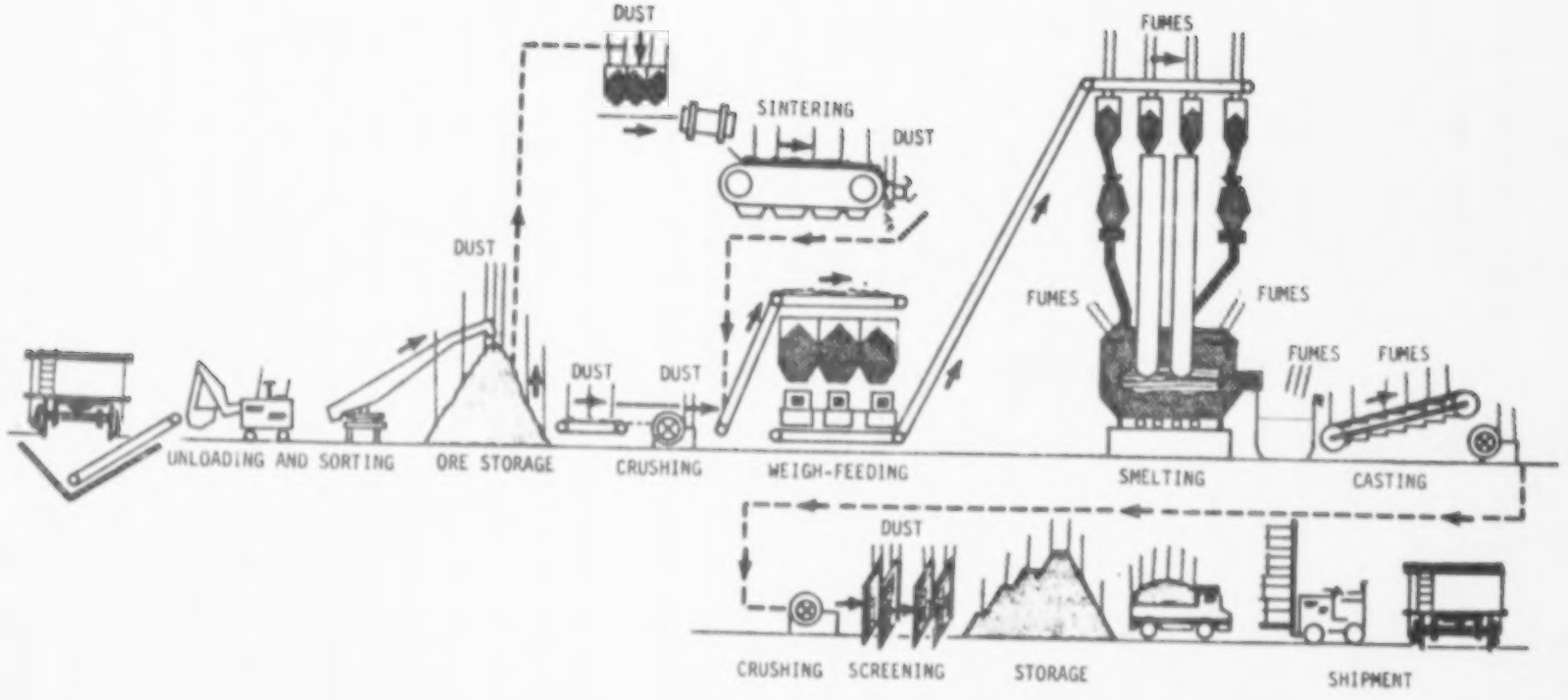

Figure 6-1. Ferroalloy production process.[3]
(Shown without air pollution control system)

6.1.1.1 Open Furnaces--

In the open furnace, a canopy hood through which the electrodes extend is located 2 to 2.7 m (6 to 8 ft) above the furnace's upper rim. This opening between the furnace and hood allows large amounts of ambient air to enter the hood and exhaust system. As the air combines with the hot gases, the carbon monoxide and most of the organic compounds are burned and the furnace emissions are diluted and cooled by the ambient air.

This type of furnace is by far the most popular in the United States because of its product flexibility. However, the large opening around the hood allows fumes to escape if sufficient draft is not provided. Control equipment must, of course, be designed to handle the large volumes of gas [8,520 to 18,720 Nm^3/MW-h (30,000 to 660,000 scf/MW-h)] inherent in an open furnace design. Many open furnaces are partially hooded to minimize air intake, and still allow complete combustion of furnace gases.

6.1.1.2 Semisealed Furnaces--

The semisealed (or mix-sealed) furnace has a water-cooled hood that fits tightly around the top of the furnace and is vented to an air pollution control system. The electrodes extend down through the hood, and raw materials are charged through annular gaps around each electrode. Because the seal provided by the raw material mixture around each electrode is not airtight, fumes may leak out unless sufficient draft is provided by the air pollution control system.

Much less outside air is drawn into a semisealed furnace than into an open furnace, and pollutant concentrations are therefore much higher. The resulting gases are also rich in carbon monoxide. Only four U.S. plants currently use the semisealed furnace. This type of furnace is not used in the United States to produce silicon metal or alloys with more than about 75 percent silicon because it cannot be readily stoked from the outside. If the high silicon mixes are not stoked, bridging and resulting pressure buildup from entrapped gases may occur in the furnace. This condition leads to "blows" (or possibly explosions) when the gas breaks through the mix or the bridged material collapses.

6.1.1.3 Closed or Sealed Furnaces--

This type of furnace utilizes a tight-fitting, water-cooled hood on top of the furnace, which is vented to an air pollution control system. Raw materials are fed through separate sealed chutes, and the electrodes penetrate the hood through seals. The furnace is thus completely sealed and operates under a slight positive pressure regulated by the fume exhaust system. No outside air enters the furnace system, and high concentrations of CO (80 to 90 percent) and particulates are emitted. Exhaust gas volumes reportedly range from 200 to 260 Nm^3/MW-h (7060 to 9180 scf/MW-h), and uncontrolled particulate concentrations range from 11.5 to 70 g/Nm^3 (5.0 to 30.6 gr/scf).[4]

From the standpoint of air pollution, a closed furnace is the most desirable because all its fumes exhaust through an emission control system and the total volume of exhaust gas is only 2 to 5 percent of that from an open furnace. Only two closed furnaces are currently in operation in the United States; both at one plant, they produce silvery pig iron containing less than 20 percent silicon and smaller amounts of other alloys. Ferroalloys with higher silicon contents are more difficult to produce in a closed furnace because they tend to bridge over in the furnace if they are not stoked, and the closed nature of the furnace makes stoking from the outside much more difficult. Lack of stoking can lead to explosions from trapped gas.

6.1.2 Process Modifications

In the United States little change has occurred in the process technology of this industry over the last 5 years. Investigation of beneficiation of feed materials, operating practices, and possible mechanical modifications to furnaces continues in an effort to improve operations and minimize emissions. Generalizations cannot be made regarding design and operation, however, because a specific evaluation of each furnace type, raw material, and product mix is required.

The split furnace is an innovative development in furnace design.[5] In this design the furnace is divided into two separate parts. The upper part is a relatively narrow ring with flat interior surfaces. This upper ring rotates more rapidly than the lower furnace portion (e.g., in one design the ring rotates at 0.1 revolution per hour (rph) while the furnace rotates at 0.01 rph.) This rotation around the stationary electrode has a mixing effect on

the furnace contents and reduces bridging and crust formation problems. A small (8.5-MW) closed split furnace producing 75 percent FeSi has been operating in Norway for several years.

A study by Battelle reports that sealed furnaces in Japan are producing FeMn (high-, medium-, and low-carbon), SiMn, FeSi, high-carbon FeCr, and SiCr.[6] In these furnaces stoking devices are inserted through seals in the furnace walls.

6.2 CONTROL TECHNOLOGY

No basic changes in control technology have occurred in this industry since promulgation of the NSPS in 1976; however, some changes in control device design and operating practices have evolved and have resulted in improved reliability of these devices on ferroalloy furnaces.

6.2.1 Fabric Filter Control System

The fabric filter control system is generally the method of choice for controlling particulate emissions from the open submerged-arc furnace. This system is used at 27 of the 31 plants in the United States. The following discussion is based on generalized information from fabric filter manufacturers and users contacted for this study.[7,8,9,10] Site-specific conditions will vary.

The predominant fabric filter system is the pressure type, in which the fan is on the inlet or dirty side of the filter. These systems exhaust directly from the top of the baghouse and have no final stack. Cleaning is accomplished by a reverse-air system, a mechanical shaking system, or a combination of both. Pulse-air cleaning systems are also used at a few installations. During the cleaning cycle, which is either timed or triggered by pressure drop and lasts for 1 to 2 minutes, the compartment is isolated from the gas stream. Because temperatures are in the 177°C (350°F) and higher range, glass fiber and Nomex fabrics are the most popular, and bag life is on the order of 1.5 to 2 years. In systems with reverse-air cleaning and glass fiber bags, air-to-cloth (A/C) ratios are approximately 37 m/h (2 ft/min) as shown in Table 6-1. In systems with mechanical shakers and Nomex bags, A/C ratios are a slightly higher 55 m/h (3 ft/min). In systems with pulse-jet cleaning, A/C ratios are 92 to 130 m/h (5 to 7 ft/min).

TABLE 6-1. REPORTED DESIGN DATA FOR FABRIC FILTER SYSTEMS

No.	Furnace Type	Rating	Product	Fabric[a]	Cleaning system	Air-to-cloth ratio, m/h (ft/min)	Inlet gas: Flow rate m^3/h (ft^3/min)	Inlet gas: Temp., °C (°F)	Particulate loading mg/m^3 (gr/ft^3): Inlet	Particulate loading mg/m^3 (gr/ft^3): Outlet	Pressure drop, kPa (in. water)	Reference
3	Open	18 MVA	Si	Glass fiber	Reverse-air	18.3 (1.0)	180,000 (114,000)					11
1	Open	48 MVA	Fe, Si	75% glass fiber 25% Nomex	Reverse-air	33 (1.8)						11
1	Open	48 MVA	Fe, Si	Glass fiber	Reverse-air	35.4 (1.94)	277,000 (175,600)					
1	Open	24 MVA	Fe, Mn	Glass fiber		32.4 (1.77)	275,000 (174,400)					11
3	Open	30 MVA	Charge chrome		Reverse-air	33.6 (1.84)	156,500 (99,200)					11
1	Semi	25 MVA		Glass fiber	Reverse-air	29.4 (1.61)	108,000 (68,500)					11
1	Open	24 MVA	Charge chrome	Glass fiber		39.6 (2.16)	275,000 (174,400)					11
2	Open	24 MVA	Cr, Si	Glass fiber	Reverse-air	39 (2.13)	365,000 (231,400) (from each pair)					11
2	Open	12 MVA	LcFe, Cr									11
1	Open		Si	Glass fiber	Reverse-air	37.8 (2.07)	170,000 (107,800)	250 (482)			3.4 (13.8)	12
1	Open	30 MW	75% FeSi	Glass fiber Nomex	Reverse-air	33.6 (1.84)	360,000 (228,240)	205 (401)				12
1	Open		FeSi FeCrSi	Nomex		50.96 (2.75)		191-205 (375-400)			4.0-4.5 (16-18)	13
1	Open		FeSi	Nomex	Reverse-air	30.77 (1.68)	200,000 (126,800)	<140-160 (284-320)	1500-3000 0.66-131	<10 (0.0044)	3.4 (13.8)	14
1	Closed	24 MVA (Taphole) 18 MW	FeMn	Dacron			78,864 (50,000)					15
			Si, charge chrome FeCrSi LC FeCr, FeSi, MgFeSi, Special maganese	Graphite-coated glass fiber	Reverse-air	25.6 (1.4)	315,400 (200,000)	177-260 (350-500)	2290 (1.0)		2-2.2 (8-9)	16
4		2-6 MW 2-12 MW	FeSi	Graphite-coated glass fiber		27.76 (1.52)	400,000 (253,600)	250 (481.7)	5500 (2.404)	50 (0.0219)		17
						37.8 (2.0)	170,000 (105,600)	250 (480)			3.4 (13.8)	

[a] Nomex and Dacron are registered trademarks.

Fabric weights vary from 170 to 475 gm/m^2 (5 to 14 oz/yd^2), and a typical bag is 28.75 cm (11.5 in.) in diameter and 9.2 m (30 ft) long. Pressure drops reach about 3.2 kPa (13 in. of water) prior to a cleaning cycle. When a system is operating properly, it achieves collection efficiencies in excess of 99 percent. Broken bags are discarded in landfill areas.

Table 6-1, which presents fabric filter design data obtained from the recent literature, shows the range of fabric filter applications. Glass fiber is the fabric cited most frequently. Air-to-cloth ratios usually ran slightly less than 37.8 m/h (2.0 ft/min). One installation reported that a higher pressure drop of 3.7 to 4.5 kPa (16 to 18 in. of water) occurred at an air-to-cloth ratio of 51.0 m/h (2.75 ft/min). The limited data reported on particulate loading before and after the filter systems showed efficiencies in excess of 99 percent.

In Europe, pretreatment of the gas stream has been accomplished by the use of a perforated rotating drum dust agglomerator filled with ceramic balls.[18] The gas stream is first cooled and then passed through the agglomerator, where the dust impinges on the ceramic balls. The resulting large particles are then collected in a fabric filter system, which uses polyester or acrylic bags and has an air-to-cloth ratio of about 91.3 m/h (5 to 1 ft/min).

6.2.1.1 Fabric Filter System Costs--

Costs of fabric filter systems depend mainly on the gas flow, type of fabric (which is related to the operating temperature), and the number of bags required (related to air-to-cloth ratio). Based on discussions with equipment suppliers[8,9] and generally used engineering factors, the cost of a fabric filter system can be calculated by the following equation:

$$\text{Cost, \$} = \frac{\text{acfm}}{\text{A:C ratio}} (5.64 + 1.95 \times \text{bag cost}) + 47{,}160$$

(Jan. 1980)

where: acfm = actual cubic feet per minute
A:C = air-to-cloth ratio, ft/min
Bag cost is expressed in \$/ft^2 as follows:

Polyester	0.65
Acrylic	0.79
Nomex	1.59
Coated glass fiber	0.74

The entire installed cost (including both direct and indirect items) would be approximately 2.4 times the fabric filter system cost (see Appendix).

A fabric filter system treating 343,000 m^3/h (200,000 acfm) and having an air-to-cloth ratio of 36.6 m/h (2 ft/min) with Nomex bags would cost $921,000, and the total installed cost would be approximately $2,200,000.

6.2.2 Scrubbers

High-pressure-drop venturi scrubbers have been applied successfully to a number of ferroalloy furnaces, especially closed and semisealed furnaces. Table 6-2[19-22] summarizes reported scrubber data. Pressure drops in the range of 13.7 to 22.4 kPa (55 to 90 in. of water) make the use of these scrubbers very energy-intensive, especially when large volumes of gas must be treated. On the order of 5 to 10 percent of the furnace power requirement may be used by the fan motor to draw the gas through the scrubber system.[23]

6.2.3 Other Control Systems

One installation of a sand-bed filter (gravel bed) was reported on a closed ferrosilicon furnace in Sweden. The furnace utilized a water-cooled hood, and filter system emissions ranged from 400 to 500 mg/Nm^3 (0.17 to 0.22 gr/scf). This concentration would result in a visible plume, but because of the fairly small quantity of gas exhausted from a closed furnace, this installation complied with an emission limit of 15 kg/1000 kg of product (30 lb/ton).[12]

One electrostatic precipitator is in operation on an open furnace in the United States. This system utilizes gas conditioning with ammonia to enhance particulate resistivity and increase collection efficiency.

6.2.4 Flares

Flares are used on closed and semisealed furnaces to reduce carbon monoxide emissions. A flare, which is essentially an open afterburner, should also reduce combustible particulate and organic matter. Because actual test data on flares are not available, an approximation of a flare's ability to reduce organic or particulate matter must be based on afterburner data.

TABLE 6-2. REPORTED DESIGN DATA FOR SCRUBBERS

Furnace				Scrubber type	L/G ratio, liters/m^3 (gal/1000 ft^2)	Inlet gas		Particulate loading, mg/m^3 (gr/ft^3)		Collection efficiency, %	Pressure drop, kPa (in. water)	Reference
No.	Type	Size	Product			Flow rate, m^3/h (ft^3/min)	Temp., °C (°F)	Inlet	Outlet			
2	Closed	48 MVA	FeMn	Venturi		20,000 (12,680)			<150 (<0.0656)			11
2	Closed	48 MVA	ChCr	Venturi		15,000 (9,510)					11.7 (47)	11
1	Closed	27 MVA	FeMn	Venturi			200-400 (392-784)					19
1	Closed	24 MVA	FeMn	Venturi		15,773 (10,000)	74 (165)					15
3	Closed	62 MVA	SiMn	Venturi	2.99 (20.78)	12,000-15,000 (7,060-8,925)		5290 (2.312)	5.94 (0.00236)	99.89	22-24 (88-96)	20
1	Open	25 MVA	FeCrSi	Venturi	2.37 (16.5)	172,416 (109,312)	260 (500)	3272-4713 (1.43-2.06)	243 (0.106)	93.9	13.7 (55)	21
1	Open	30 MW	SiMn	Venturi	1.96 (13.6)	208,990 (132,500)	260 (500)	2974 (1.30)	22.9-38.9 (0.010-0.017)	98.96	14.2 (57)	21
1	Open	30 MW	H.C. FeCr	Venturi	1.96 (13.6)	208,900 (132,500)	249 (480)	2448 (1.07)	43.5 (0.019)	98.2	14.3 (57)	21
1	Closed	15 MVA	FeSi	Venturi		1.6-1.9 Nm^3/kg 55-65 scf/ton alloy	200-300 (392-572)	100,000-150,000 (43.7-65.6)		99.9		22

The combustion efficiency of a flare is primarily a function of temperature, turbulence, oxygen content, and residence time. Because of the rapid cooling and dilution inherent in flares, residence time is short (about 0.1 second).* Temperatures of 581° to 994°C (1078° to 1822°F) have been measured experimentally in a small pilot plant equipped with flares burning natural gas.[24] Combustion of liquid droplets requires vaporization, and the rate at which a droplet burns is dependent on its size and the temperature. This relationship is expressed by:[25]

$$t = \frac{29{,}800\ md^2}{PT^{1.75}}$$

where: t = time required for combustion, seconds
P = partial pressure of oxygen, atmospheres
m = molecular weight
d = droplet diameter, cm
T = temperature, °K

For a 200-molecular-weight hydrocarbon, this formula gives a residence time of 0.0084 second at 1000 K (1340°F) and an oxygen content of 0.1 atm for a 50-micrometer droplet. This relationship indicates that more than enough residence time exists in a flare to vaporize and burn small droplets.

For solids, the combustion relationship is much more complex and cannot be readily predicted. For a 1-micrometer particle, estimated combustion times range from 0.043 second at 793°C (1460°F) for a coal char to 175 seconds at 827°C (1520°F) for a soot particle.[26] Based on this minimum amount of data, one can only assume that most solids composed of volatile organic matter probably would be burned in a flare, whereas inorganic and carbon particles would not be burned.

6.3 CONTROL OF TAPPING EMISSIONS

Molten ferroalloy is removed from the electric submerged-arc furnace through a tap hole that is flush with the floor of the carbon hearth. The tap hole is closed by the manual insertion of a carbon graphite plug after completion of tapping or by means of a hydraulic or pneumatic mud gun.

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*Based on an assumed 16.6 m/s (50 ft/s) gas velocity and a 1.7 m (5 ft) long flame.

When the molten metal is ready to be tapped, the tap hole is pierced by drilling, by use of a single shot pellet fired from a gun-like piece of equipment, or by oxygen lancing.

The molten ferroalloy passes through the open tap hole to a trough arrangement fixed to the furnace shell and then to runners that direct it to a ladle or, in some instances, to a runner going directly to a casting bed. When the ladle is filled with the molten metal, an electric overhead traveling (EOT) crane transports it to the point of deposit, where the metal is then poured into a bull ladle, a reaction ladle, a pigging machine, or a shallow cast bed.

Emissions occur during the following:

- Piercing of the tap hole, if drilling or lancing is used
- Tapping at the furnace proper, the runners, and ladle
- Transporting in the ladle
- Pouring into the bull ladle, reaction ladle, pigging unit, or the cast bed.

Problems encountered in the control of emissions from retrofit installations include lack of space to install hooding and still have sufficient room for operators to do their work; ducting and hooding interference with the operation of the EOT crane at the tap hole area; and hooding difficulties at the ladle, especially during pouring, because of floor layout, design, and existing equipment. Proper planning could prevent most of these problems in new furnaces.

Since furnace tapping takes 10 to 15 percent of the total cycle time,[23] significant emissions can occur. When the molten metal is poured into a bull ladle, emissions are very high but of a short duration; whereas, when the metal is poured into a reaction ladle, emissions are both significant and of rather long duration. Emissions are also high but of a short duration when the metal is poured from a ladle to a casting bed; however, they are both higher and prolonged when the molten metal goes directly from the furnace to an adjacent cast bed during tapping.

Several possible measures are available for reducing emissions during tapping in new furnaces.

- Hooding could be designed to minimize emissions; instead of in arrangement in which an EOT crane transports the ladle, a ladle car on tracks or a rubber-tired unit with a ladle tilting device operating under a canopy tunnel enclosure could be used to transport the molten metal to the bull ladle or casting bed; casting beds could be designed to eliminate crosscurrents and emissions could be collected overhead; and reaction ladle operations could be designed to take place in an enclosed building and emissions could be collected overhead. In each instance, the control equipment would be a fabric filter system.

- It may be possible to enclose and vent the tap area around each furnace and to use pendant-operated EOT cranes to service the area, independent of the main EOT cranes. Airflow would be 70.7 to 94 m^3/s (150,000 to 200,000 cfm).

- Another possible control method is the use of a telescopic emission capture device (see Figure 6-2).

- The use of an air curtain in the tapping area would permit the crane access to the tap hole area, runners, and ladle (see Figure 6-3). Airflow would be 16.5 to 21.2 m^3/s (35,000 to 45,000 cfm).

- Ladles could be equipped with covers, but this would increase handling time and maintenance.

- The use of a vermiculite slag blanket would minimize emissions in transportation, but it would also create pouring problems.

- A verticle takeoff on the hood over the tapping area could help to alleviate fugitive emissions.

- A total building enclosure with an overhead collection system would also minimize fugitive emissions to the atmosphere, but would not achieve compliance with the NSPS since visible emissions are determined at the hood.

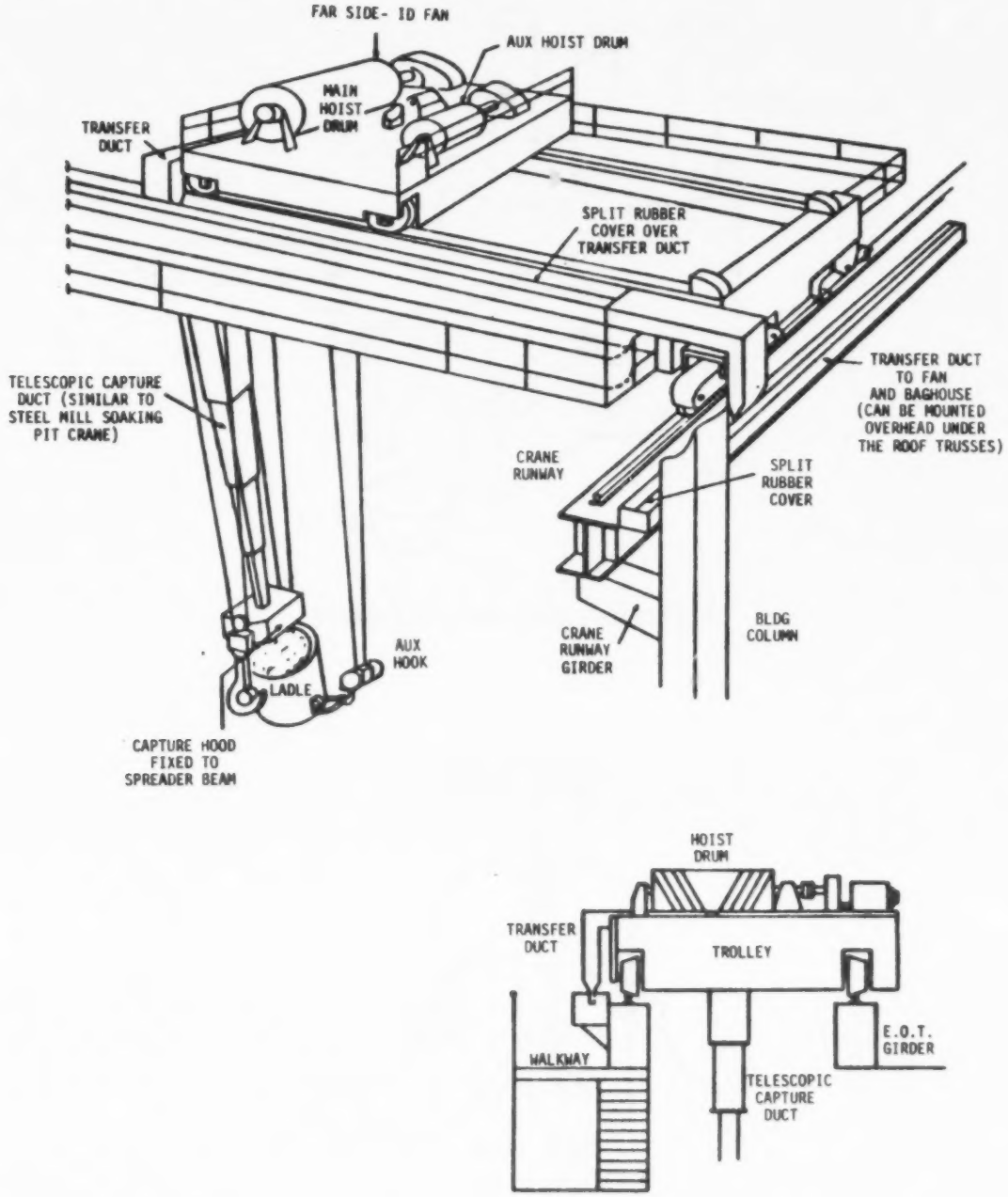
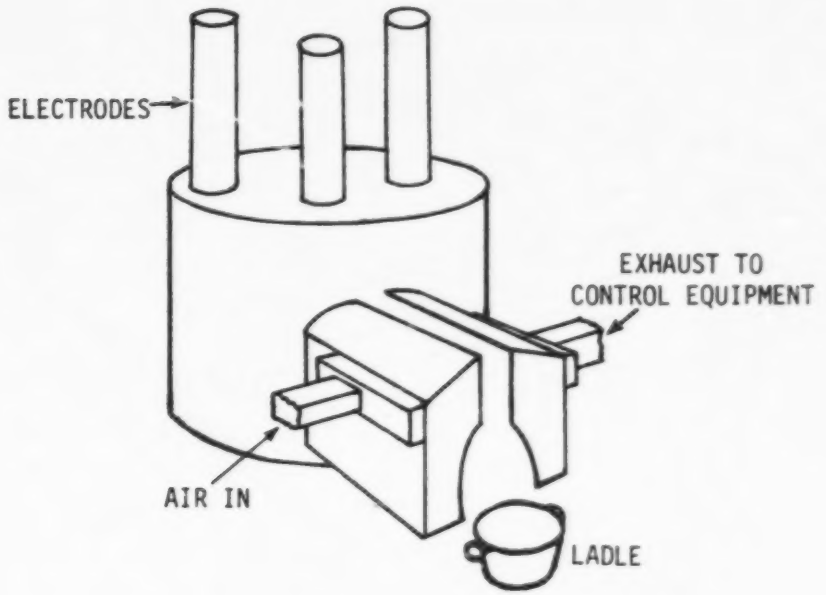


Figure 6-2. Ladle/EOT crane fugitive emission collection system.



ELECTRIC SUBMERGED ARC FURNACE

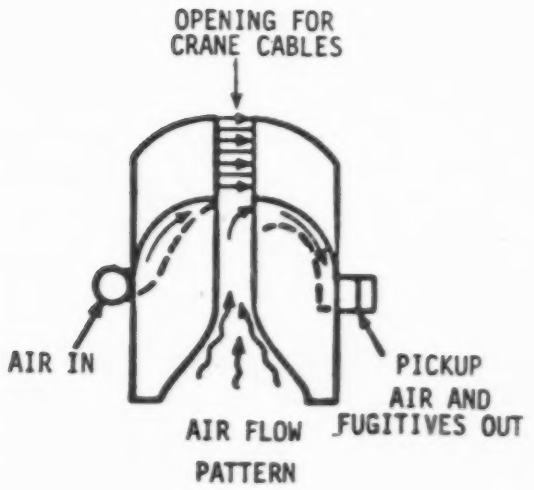


Figure 6-3. Air-curtain fugitive control system.

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SECTION 7

CONCLUSIONS

7.1 INDUSTRY GROWTH

Total domestic production of ferroalloys has remained fairly static since promulgation of the NSPS in 1976. Because no new furnaces have been built or modified, no furnaces are currently subject to the NSPS. The industry's annual growth rate has declined from 1.5 percent to zero. Two large plants (one at Brilliant, Ohio, and the other at Sheffield, Alabama) have been shut down and furnaces at many plants have been shut down and some have been dismantled. In 1971, 158 electric arc furnaces were in operation, 145 for ferroalloy production and 13 for calcium carbide production.[1] Currently, approximately 89 are producing ferralloys and 7 are producing calcium carbide. No new furnaces are expected to begin operation in this country in the next few years. This decline in the industry has resulted from a rapid increase in imports and the fairly static condition of the domestic steel industry.

Another trend in this industry is the purchase of U.S. plants by foreign-based companies. Approximately 50 percent of the capacity of the plants in the United States are now owned by or being sold to foreign companies.

7.2 PROCESS CHANGES

No new process technology has been introduced to this industry, and the basic technology has remained unchanged. The electric submerged-arc furnace is still by far the predominant method for producing ferroalloy. The metal-othermic and electrolytic processes are still used for speciality alloy production, but they account for only about 5 percent of total alloy production.

Advances in furnace design include the sp it rotating furnace, which minimizes buildups and bridging of the mix and thereby reduces the amount of external stoking required.[2] This design allows the furnace to be more enclosed than an open furnace and thus decreases fugitive emissions around the hood. No split rotating furnaces are currently used in the United States.

7.3 CONTROL EQUIPMENT

No innovations in control equipment or control systems have been developed, but operation of the existing equipment has improved as experience has been gained. Fabric filter systems are the most common means of particulate control. When properly maintained, they can reduce emissions to a level that complies with applicable state regulations. In this country, high-pressure-drop scrubbers are used mainly on semisealed and closed furnaces. These devices can reduce particulate emissions by more than 99 percent and can achieve emission levels that meet applicable regulations. In addition, scrubbers reduce organic emissions by 16 to 97 percent.

Flares are used on closed and semisealed furnaces to reduce carbon monoxide emissions. They probably also reduce organic and combustible particulate emissions, but quantitative data on their efficiency are not available.

An electrostatic precipitator is used effectively on one open furnace in this country.

Control of fugitive particulate emissions generated by furnace tapping, ladle transfer, and casting continues to be a problem on existing furnaces because it is difficult to retrofit adequate hooding systems. This is a site-specific problem that does not require new technology. Such control could be designed into a new installation more easily than it can be retrofitted into an existing one.

7.4 EMISSIONS

New data on emissions from ferroalloy furnaces have been gathered as part of EPA's environmental assessment studies. These studies included tests to determine the amount of particulates, organics (including polynuclear

aromatic hydrocarbons), and trace metals in the emissions. Also, a number of tests were conducted on existing furnaces to determine whether they were in compliance with state regulations.

7.4.1 Organic Emissions

Of prime interest among the new data are those on organic emissions, particularly POM. Quantitative data obtained to date are very limited, and only rough estimates of industrywide organic emissions can be made. These are shown in Table 7-1.

TABLE 7-1. ESTIMATED ORGANIC EMISSION RATES AFTER CONTROL

Furnace type	Control device	Total organic emission,[a] kg/MW-h	(lb/MW-h)
Open	Fabric filter	0.20	(0.44)
	Scrubber	0.29	(0.63)
Semisealed	Scrubber	0.15	(0.33)
Closed	Scrubber	0.01	(0.022)

[a]Before any further reduction by flares.

When these emission rates are multiplied by the respective furnace capacities, the estimate of total annual organic emissions from submerged-arc furnaces is 2220 Mg (2440 tons), based on 70 percent utilization. Data presented in Section 5 on polynuclear organic matter show that POM compounds represented from 8.3 to 75 percent of the total organic emissions after a scrubber and before the flare. The single test on a semisealed furnace after a scrubber showed that BaP accounted for 0.84 percent of the organic emissions.

The ground-level ambient air impact car be estimated by an atmospheric dispersion model. Table 7-2 presents ground-level concentrations of organics obtained by utilizing EPA's PTDIS dispersion model for selected 20-MW plants at a windspeed of 4.4 m/s (10 miles/hour) and a Class C atmospheric stability. These estimates show that the highest levels occur 1 to 2 km from the stack and that an open furnace with a scrubber represents the worst case with 24-hour concentrations of 1.1 to 1.6 $\mu g/m^3$. This is because the scrubber water lowers the stack gas temperature, which in turn decreases dispersion.

TABLE 7-2. ESTIMATED GROUND LEVEL CONCENTRATION OF ORGANICS FROM A 20-MW FURNACE

Furnace type	Control device	Exit temperature, °K (°F)	Emission rate		Averaging time, h	Ground-level concentrations at specified distance from stack, μg/m³				
			g/s	kg/MW-h		0.5 km	1.0 km	2.0 km	10 km	20 km
Open[a]	Fabric filter	450 (350)	1.11	0.20	1	0.0022	0.067	0.83	0.17	0.067
					24	0.0007	0.021	0.27	0.057	0.022
Open[a]	Scrubber	333 (140)	1.61	0.29	1	0.71	5.1	3.6	0.27	0.10
					24	0.23	1.6	1.1	0.087	0.032
Semisealed[b]	Scrubber and flare	1033 (1400)	0.833	0.15	1	0.93	3.4	2.0	0.14	0.050
					24	0.30	1.1	0.64	0.045	0.016

[a] Stack height = 25 meters.

[b] Stack height = 30 meters.

Ground-level concentrations of other compounds, can be estimated by a direct proportion of the values in Table 7-2. Thus, if BaP comprises 0.8 percent of the total organic emissions from a semisealed furnace, the average 24-hour ground-level concentration would be: (0.8% x 0.64 $\mu g/m^3$) = 0.005 $\mu g/m^3$ at a point about 2 km from the stack.

None of the ferroalloy plants practices direct control of organic emissions. Scrubbers used for particulate control also reduce organic emissions and would be expected to reduce POM compounds by a similar amount. The POM compounds thus end up in the wastewater stream, where they could cause a disposal problem. Flares used for CO control would also be expected to reduce organic and POM emissions; however, data pertaining to the extent of control are lacking. The use of open furnaces, in which combustion of CO and other combustible matter takes place in the furnace, minimizes organic emissions.

7.4.2 Trace Metal Emissions

Section 5 presented limited data on emissions of trace metals. The major metallic emissions are composed of oxides of the product alloys produced in the furnace. The trace element emissions, which are related to impurities in the ores, may vary widely. Ferroalloy plants with high efficiency particulate controls as required by most state and local regulations are not generally major sources of lead. Lead emissions are subject to the national ambient air standard of 1.5 $\mu g/m^3$.

Cadmium, arsenic, and copper compounds are also emitted by ferroalloy furnaces. Again emission data are sparse and highly variable. Table 7-3 presents estimated emissions of trace metals that are or may be designated as hazardous pollutants under Section 112 of the Clean Air Act.

TABLE 7-3. ESTIMATED EMISSIONS OF HAZARDOUS TRACE METALS AFTER CONTROL

Metal[a]	Estimated Emissions	
	mg/MW-h	g/24 hours[b]
Arsenic	62	30
Beryllium	0.02	0.01
Cadmium	17[c]	8.2
Copper	8.5[c]	4.1
Mercury	4	1.9
Lead[d]	2.7	1.3

[a] Beryllium, mercury, and arsenic are currently listed under Section 112 of the Clean Air Act. The other metals are being considered for possible designation as hazardous pollutants.

[b] For a 20-MW furnace.

[c] Based on uncontrolled emission measurement and assumed 99% reduction in a scrubber.

[d] Designated as a criteria pollutant, not a hazardous pollutant.

These data show that mercury and beryllium emissions are approximately 1.9 and 0.01 g/day respectively. These are fairly low levels compared with the allowable emission of 10 g/day for beryllium and 2300 g/day for mercury for other processes as designated in Section 112 of the Clean Air Act. Lead emissions are also relatively low.

7.5 SOURCE TESTING METHOD EVALUATION

The Standards of Performance for new ferroalloy facilities specify the testing methods for measurement of the emissions. The testing methods described (specifically Method 5) have been used successfully on wet scrubber and enclosed fabric filters.

Several precautions have been taken by various testing teams to ensure accurate data collection and safety of sampling personnel. For example, for sampling at the inlet to a control device, the use of a cyclone of large volume (200 ml)[3] is recommended to minimize the need for changing plugged filters during the test run. This allows uninterrupted sampling of integral

furnace cycles. If a filter change is necessary, it should be made at the point in the furnace cycle where the run began.

High carbon monoxide content is inherent in the production of ferroalloys in sealed and semisealed furnaces. The testing method states that when the CO content is greater than 10 percent by volume, the heating systems specified in Method 5 should not be used. Electrical-resistance heating systems can create an explosion hazard in high CO content gases. Although the absence of probe and filter heating systems may not bias the results of tests on fabric filter control devices, it will bias the results of tests at the outlet of wet scrubbing systems because of condensation. Use of a steam heating system is recommended when sampling the exit from wet collectors.[4] The probe and filter portions of the sampling system should be heated to 120° ± 14°C (250° ± 25°F), as specified in Method 5.

As a safety precaution, the vacuum pump should be properly grounded to minimize the chance of sparking.[3] It is also recommended that a length of large diameter tubing be attached to the exit end of the meter box orifice. This tubing should be vented away from all personnel, to minimize the health hazards associated with high CO content in the gas stream.[4,5] Before sampling begins, the orifice should be calibrated with the length of tubing attached, to insure isokinetic sampling conditions.

In stacks with high CO contents, high negative static pressures, and high temperatures [540°C (1000°F)], an air-tight seal should be provided around the probe. In one case, an improper seal reportedly caused air to leak into the stack and ignite the gas.[4]

In addition to EPA Method 5, Level 1 Source Assessment Sampling Systems (SASS trains) have been used to characterize emissions from ferroalloy furnaces.[4,6] Gas chromatography and electron capture have been used successfully for the determination and quantification of reduced and oxidized sulfur compounds[4], and gas chromatography by flame ionization has been used for the determination and quantification of hydrocarbon compounds.[4]

The CO content of the gas stream associated with the production of ferroalloys has been measured by EPA Method 3 procedures, with minor difficulties. A standard Orsat apparatus with the volumetric capacity to measure CO quantities in the 30 to 80 percent range should be used for testing sealed furnaces.

Testing open fabric filters presents difficulties because an enclosed duct is not available and a complete traverse of the open area is impossible. A specific test plan must be developed for each site. Erection of a temporary stack on one module of the fabric filter system (to facilitate measurement of particulate concentrations) and measuring total gas flow at the fabric filter inlet have been used to obtain emission rates:[7,8] the amount of ambient air induced into a fabric filter system has been estimated by making heat balances around the system.[7] Measurements after flares have not been attempted because of inaccessibility and the unconfined nature of a flare.

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SECTION 8

RECOMMENDATIONS

8.1 CHANGES IN REGULATIONS

No changes in particulate emissions regulations are recommended at this time. Limited additional test data for determination of compliance with State emission regulations have indicated particulate emissions also comply with the NSPS. Regulations in other countries are generally less restrictive than U.S. regulations, except those for closed furnaces.

Visible emissions from control equipment vents are usually in compliance with the NSPS requirement of 15 percent or less opacity, except during malfunctions. Most plants are also in compliance with existing state regulations. Visible emissions from tapping are a problem on existing furnaces, but technology available for hooding and control of new furnaces should enable them to comply with the NSPS. No change in the visible emission levels is recommended.

Flares are used on streams with high CO content, and there is no need to change the CO emissions limit.

8.2 AREAS OF FURTHER STUDY

Although emissions of many organic compounds have been identified from open, closed, and semisealed furnaces, data are currently insufficient to determine the magnitude and impact of these emissions; especially after control devices. It is therefore recommended that tests be performed on open furnaces equipped with fabric filter control systems to determine the quantity of the organic and especially POM compounds in the exit gas stream and how effectively they are controlled by fabric filtration systems. A determination of how much a flare reduces organic and POM concentrations will be necessary for an assessment of emissions from closed and semiclosed furnaces.

APPENDIX

COSTS FOR FABRIC FILTER SYSTEMS

1. Data required:

   - Gas flow and gas temperature to baghouse
   - Type of ferroalloy produced
   - A/C ratio
   - ΔP = 13 in. of water
   - Reverse air and insulated baghouse

2. Baghouse cost:

$$\$ = \left(\frac{5.64 \times \text{acfm to baghouse}}{\text{A/C ratio}}\right) + 1.95 \left(\frac{\text{acfm to baghouse} \times \text{bag cost}^{a}}{\text{A/C ratio}}\right) + 47{,}160$$

[a] Bag cost, $/ft^2, and temp, °F max.

Polyester/dacron	$0.649 - 275°F
Glass (coated)	0.740 - 500°F
Nylon	0.773 - 200°F
Acrylic	0.791 - 285°F
Nomex (average)	1.588 - 375°F

3. I.D. fan and motor for ΔP = 13 in. of water

$$HP = \frac{0.00157 \times \text{acfm} \times 13}{0.65}$$

$$\text{Cost of fan and motor} = 33{,}300 \left(\frac{\text{acfm to baghouse}}{150{,}000}\right)^{.6}$$

If the acfm is greater than 50,000 cfm, two or more I.D. fans are used; the equation shown covers up to 160,000 cfm; if two or more fans are used, costs should be calculated on acfm per fan and then multiplied by the number of fans and motors used.

4. Installed costs:

Direct	Material and equipment	Installation
Fabric filters, fans, and motor	x	0.4x
Instrumentation and controls	0.01x	0.005x
Electrical (no transformers)	0.05x	0.05x
Piping	0.01x	0.01x
Insulation	Supplied/ baghouse	0.05x
Painting	0.001x	0.009x
Site preparation	0.005x	0.005x
Foundations	0.01x	0.01x
Structural work	0.01x	0.01x
	1.096x	0.584x

Indirect	
Engineering	0.10x
Contractor's fee	0.15x
Field expenses	0.05x
Freight	0.04x
Offsites	0.02x
Taxes (if not exempt)	0.025x
Allowance for startup, etc.	0.015x
Spares	0.02x
Contingency	0.06x
Escalation	0.075x
Interest during construction (12%/yr)	0.162x
	0.717x

Total installed cost = 2.397x. [Total installed cost does not include ducting to the baghouse or to the stack nor the stack cost. (Note: Most of ducting and stack costs would be part of the furnace costs). Dust removal would be accomplished by plant's vehicle. No costs for disposal area.]

5. Annual Operating Costs:

Utilities

a. Electricity:

I.D. fan: $0.00314 \times 0.746 \times$ baghouse acfm $\times 8760 \times 0.035$
$= 0.6823 \times$ acfm = $

Reverse: $0.0614 \times 0.00314 \times 0.746 \times$ acfm $\times 8760 \times 0.95 \times 0.2 \times 0.035 = 0.0084 \times$ acfm = $

Screw conv.: $\frac{11 \times 0.746 \times \text{acfm} \times 0.25 \times 0.035 \times 8760}{440{,}000}$

$0.00143 \times$ acfm = $

b. Operations

1. Labor	1 man/shift x $8.50/h x 8760	=	$ 74,500
2. Supervision	15% of labor	=	11,200

c. Maintenance

1. Labor	1 man/shift x 9.00 x 8760	=	78,840
2. Materials:	$\frac{\text{acfm (baghouse)}}{\text{A/C ratio}} \times \frac{\text{bag cost \$/ft}^2}{2}$ =		
	: 0.1 (b.1 + b.2 + c.1)	=	16,500

d. Overhead

1. Plant	0.5 (b.1 + b.2 + c.1)	=	82,270
2. Payroll	0.2 (b.1 + b.2 + c.1)	=	32,908

e. Fixed costs:

Depreciation $\frac{100}{\text{equip. life (15 yr)}}$	=	6.67%
Interim replacement	=	.35%
Insurance	=	.30%
Taxes	=	2.00%
Capital cost	=	12.00%
		21.32%

$0.2132 \times$ total installed cost = $

f. Dust removal

1 truck per day - 2 h/day - captive truck
2 (8.50) x 1.9 x 365 x .95 = $11,200

Total annual operating cost
is total of all items $_____